OPTICAL TECHNOLOGY
APOLLO EXTENSION SYSTEM
PART II

DEFINITION OF WORK TASKS

CONTRACT NAS 8-20256

SPACE DIVISION CHRYSLER CORPORATION

OPTICAL TECHNOLOGY
APOLLO EXTENSION SYSTEM
PART II

DEFINITION OF WORK TASKS

CONTRACT NAS 8-20256

September 27, 1966

Approved by: W. W. Kloepfer
W.W. Kloepfer
Program Manager

CHRYSLER CORPORATION SPACE DIVISION, MICHOUD ASSEMBLY FACILITY
P.O. BOX 29200, NEW ORLEANS, LA. 70129

2856-9-20-66

PRECEDING PAGE BLANK NOT FILMED.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

DEFINITION OF WORK TASKS

I. INTRODUCTION

The Chrysler Corporation Space Division, Kollsman Instrument Corporation, Sylvania Electronic Products, Inc., team was awarded one of two concurrent Optical Technology Apollo Extension System (OTAES) study contracts, effective November 8, 1965. The study is sponsored by the NASA Headquarters Office of Advanced Research and Technology, and is managed by the NASA George C. Marshall Space Flight Center. The purpose of this study is to define and justify technological requirements for large optics in space and planetary communications and to determine the alternative development approaches which will satisfy these goals.

As one of the two Phase A prime contractors, Chrysler has full responsibility for systems integration and program management, as well as a "team member" responsibility for experiment development. Kollsman as the optics and fine guidance subcontractor, and Sylvania as the RF and optical communications systems subcontractor, have major responsibilities for experiment development.

On March 8, 1966, the initially contracted Part I study was completed with the identification, definition, and requirement justification of 36 optical technology experiments; the derivation of mission, orbit, and launch vehicle requirements; and the investigation of the experiment constraints imposed by spacecraft and ground support systems. As the Part I study progressed, the need for additional detail in the areas of compatable experiment grouping and OTAES Concept justification for space testing became evident. Consequently, Part I was extended through October 22, 1966, for additional studies in these areas.

The OTAES Program represents Chrysler's further commitment to the major space endeavors of the early post-Apollo period and, therefore, receives the attention of the highest levels of management. It is the major element of the Chrysler Corporation Space Division's plans for further space Astronomy.

The Part II effort will emphasize the cost schedule and the reliability and critical development elements of the recommended experiments, both singly and in groups. The following sections present a detailed work plan commensurate with the present Part II work scope.

II. TECHNICAL APPROACH

A. STUDY PLAN

The purpose of the Part II OTAES study is to provide a clear definition of the technology development alternatives from which NASA has to choose in advancing the area of space optics. This includes a definition of the major factors that will influence these decisions, such as cost, schedules, and reliability. Furthermore, the recommended OTAES space experiments will be shown in context with this over-all development plan with sufficient definition to indicate also the alternatives to implement these experiments.

Much of the basic material required to meet this objective has been generated during Part I of the OTAES study. What remains is a better definition of the over-all development plan, definition of cost alternatives, increased definition of OTAES experiments, and their integration into <u>feasible</u> mission concepts.

In a program such as OTAES the word 'feasible' warrants much consideration. Due to the developmental nature of space optics, there is a family of technical problems that are immensely difficult and have yet to be solved. These problems range over various levels of integration. For instance, a single recommended OTAES experiment is addressed to problems primarily at the assembly level. The implementation of two or more experiments introduces problems that involve various subsystems such as, for example, power, stabilization, and data management. The integration of a set of experiments into a single mission introduces such problems as time phasing, thermal control, manned operation, volume constraints, weight constraints, and accessibility. The feasibility of a single experiment, to be adequately assessed, must be considered through all levels of integration. No one set of problems is independent of or more important than problems at a different integration level. The problems associated with integrating large precision optical systems with space missions, particularly manned missions, have yet to be solved. These are equally as imposing, difficult, and novel as the set of problems at the experiment level. One objective of the OTAES Part II study is to provide NASA with a meaningful assessment of experiment feasibility. This means that OTAES experiment design alternatives and the necessary data to evaluate these alternatives will be generated. Again, much of this work has been started during Part I.

The Part II study is organized into five Tasks. These are shown below and in Figure 1:

Task 1.0	Optical Technology Development Plan
Task 2.0	OTAES Experiments
Task 3.0	Experiment Integration
Task 4.0	Spacecraft and Subsystems
Task 5.0	Resources Analysis

Each of these tasks is discussed at the sub-task level in the following section.

STUDY TASK PARAGRAPH REFERENCE	TASK AND SUB-TASK DESCRIPTION	MONTHS OF PART II EFFORT FOLLOWING EXTENSION 0 1 2 3 4 5 6
1.1	OPTICAL TECHNOLOGY NEEDS	
1.2	OTPICAL TECHNOLOGY DEVELOPMENT PLAN	
2.1	OTAES EXPERIMENTS	
2.2	RECOMMENDED EXPERIMENTS REVIEW	
3.1	COMPARATIVE RELIABILITY ANALYSIS	
3.2	MANNED OPERATION	
3.3	GROUND STATION	
3.4	MISSION PROFILES	
3.5	TELESCOPE CONFIGURATIONS	
4.1	SPACECRAFT CONFIGURATION	
4.2	CONTROL AND STABILIZATION	
4.3	POWER SYSTEMS	
4.4	DATA MANAGEMENT	
4.5	ENVIRONMENTAL CONTROL SYSTEMS	
4.6	CREW ACCESSORIES	
4.7	THERMAL CONTROL	
4.8	SYSTEMS RELIABILITY, SPECIFICATIONS, AND TESTING	
5.1	DETAILED PLANS	
5.2	MISSION AND SPACECRAFT COST ALTERNATIVES	
6.1	PRESENTATION	
6.2	REPORT	

Figure 1. Proposed Schedule for Extension of Part II Effort

B. TECHNICAL TASKS

1.0 OPTICAL TECHNOLOGY DEVELOPMENT PLAN

The purpose of this Task is to provide an over-all development plan for space optics. Recommendation 18 of the OTAES Part I study summary stated, "It is recommended that an over-all optical technology program plan be explicitly detailed. This plan should indicate the relationship of space experiments and related ground-based tests to other programs, including those which do not include space testing." The purpose of this task is to provide the framework of such a plan.

This task involves two sub-tasks. The first is the identification of NASA objectives and needs in space optics through the 1970 decade. The second is the presentation of a technology development plan to satisfy the needs.

1.1 Major Objectives and Needs

The purpose of this sub-task is to identify observational objectives and otpical technology needs in the four areas of: astronomy, earth remote sensing, meteorology, and interplanetary missions. The sources for the objectives are scientific articles, industrial reports from NASA-funded studies, and reports such as the Woods Hole Summer Study. The result is a list of scientific observations important for future space science. Included in the list with each observation are the performance parameters and their value range. Performance parameters are figures of merit that characterize the observation. (As an example, take the observation of the sun's quiet corona. Spectral observations of the quiet corona are important for an understanding of the chromosphere-corona interface. The performance parameters for the observation are spectral resolution, spatial resolution, and wavelength. The required spectral resolution of 10^3 $(\lambda/\Delta\lambda)$. Some important spectral lines are those of NeVII (465°A), NeVIII (780°A), and MgIX (368°A). Spatial resolution of 2 secs of arc is necessary to reveal details of the interface.[1]) Figure 2 is an example of information displayed in this format. The values of the performance parameters determine instrument requirements. The next part of this sub-task is to determine the capability of present instruments; that is, the current state of the art. A survey of the state of the art indicates the areas where technological development should be concentrated.

In Part I of the OTAES study the listing of observations for the four areas is fairly complete, although continuing study is necessary to keep the information up to date and to obtain more detail in the areas of meteorology and earth remote sensing.

A beginning survey of the state of the art was made in Part I using the values of the performance parameters as a guide. For example, high spectral resolution (of the order of 10^5) is a requirement for many space objectives--the

1. Space Research - Directions for the Future, Report of a Study by Space Science Board, Woods Hole, Mass., 1965, page 210.

SOURCE: ORL Experiment Program, Volume B, Part XI, Astronomy/Astrophysics, February 1966.

OBSERVATION	PERFORMANCE PARAMETERS	VALUE RANGE
Profiles of the Lyman α Absorption Line of Interstellar Hydrogen (To Find Distribution of Interstellar Hydrogen - Important to Study of Galactic Structure)	Wavelength Spectral Resolution Spatial Resolution	1216Å 10^5 0.1 sec
Spectra and Photographs in UV and Visible of Early Type Stars for Stellar and Planatary Systems Evolution.	Spatial Resolution Spectral Resolution Wavelength	10^{-3} - 10^{-5} 10^5 } 10^3 0.01Å-3mu } 0.01-100m
Observe UV and IR of Stars Classified Spectrally, Map Globular Clusters to Find UV and IR Emission, Then High Resolution. To Improve H-R Diagram of Globular Clusters to Find Their Evolutionary Path. (Spectrascopic and Photometric).	Wavelength Spectral Resolution Spatial Resolution	0.9mu - 3 mu 10^5 0.1 sec
UV Spectra of Stars. For Better Theoretical Stellar Models, Extend H-R Diagram, Determine Cosmic Abundances. To Understand Cosmic Processes. Will Get Improved Values for Total Fluxes and Profiles and Equivalent Width of Resonance Lines in UV.	Wavelength Spectral Resolution Spatial Resolution	0.01Å - 15mu 10^4 0.1 sec

SOURCE: L. Goldberg, "Stellar and Interstellar Observation," Space Age Astronomy, 1962.

Search for Infrared Sources.	Wavelength	0.7 to 30 μ
Infrared Interferometery		
Ultraviolet Map of Celestial Sphere.	Field of View	5 to 6 degrees
Distribution, Brightness, Size, and Red Shifts of External Galaxies.	Limiting Magnitude	

Figure 2. Astronomical Observation and Performance Parameters

profile of the Lyman and absorption line of interstellar hydrogen, contours of stray lines in bright stars, and resonance lines of NI1200°A and Si2515°A, to name a few. It was clear that present instruments cannot achieve spectral resolution of 10^5. For a more detailed study of the state of the art, it is necessary to first analyze the factors contributing to improvement of spectral resolution. Higher spectral resolution depends on several parameters; for example, improved pointing accuracy, high resolution diffraction gratings, and high resolution sensors. It is necessary to analyze the contributions of these factors in detail by performing an analytical error analysis. This analysis then sets the required performance bounds for the contributing parameters, such as pointing accuracy. Given the state of the art in many specialized areas, a more explicit program of optical technology development is possible. The sources for the state of the art include the sources for the space objectives and, in addition, NASA and Air Force funded studies directed specifically to improvement of optical technology (for example, Technical Operations Corporation of Boston, Massachusetts, is currently under contract by the Air Force to develop silver Solide emulsion with resolutions as great as 500 line pairs/mm.), and experiments for current or planned balloon, rocket, and spacecraft programs.

The output of this sub-task is the foundation work for the development of the Major Technology Development Plan, Sub-task 1.2.

1.2 Major Technology Development Plan

The purpose of this sub-task is to develop a major technology plan which satisfies the needs identified in sub-task 1.1. The technology plan is a blueprint for the development of optical technology. The plan starts at the present day with the space objectives and optical technology needs and ends in the future when the optical technology will be developed to the extent that it will be possible to achieve the space objectives.

During Part I, planning effort was directed toward a detailed study of each of the 15 recommended experiments. Emphasis was given to the ground development program leading to the OTAES space experiments. For each experiment there is a detailed prerequisite technology identification and experiment development schedule. The experiments were then considered in various groups for integration and candidate mission development. Only preliminary study was given to the necessary ground development program not associated with space testing, and very little study was given to the ground development program following OTAES space experiments. Some of the post-OTAES ground program will be a continuance of the purely ground program, some of it will result from new discoveries, and some will follow and be directly related to the information gained from OTAES space experiments. During Part II, information on all of these phases of required development will be incorporated into a major development plan. Non-OTAES and post-OTAES ground programs will be developed only to the extent of recognizing major milestones similar to the level of definition in the Part I prerequisite OTAES technology.

In Part I of the OTAES study, a commonality of optical technology needs was noted. A commonality of needs implies a commonality of instruments. Since in many cases the needs and thus the instruments are not too greatly varied, it is possible to find space goals broad enough so that when it is possible to achieve these goals it is also possible to fulfill the many other objectives. Two major goals were selected in Part I, for which first iteration plans were developed. These were a 120-inch aperture Manned Orbiting Telescope and an Interplanetary Optical Communication System. In Part II additional goals will be selected (in direct correlation to the more detailed work planned for sub-task 1.1). For example, two possible goals are an orbiting solar observatory and an earth remote sensing laboratory.

In summary, the Part II effort will include milestone definition of non-OTAES related ground development programs for several NASA goals. The OTAES related development will be shown in context with this plan, and the interrelationship between the various development phases will be shown in the form of constraining factors. Figure 3 is a simplified development program for an interplanetary optical communication system. Non-OTAES related ground based testing has not been shown. This will be developed during Part II. This figure does show the relationship of the OTAES experiments (note OTAES experiment 1). This relationship is more clearly depicted in Figure 4 in which the time phasing is shown for the prerequisite technology required to support OTAES experiment 1, Heterodyne Detection on the Earth. During Part II this time phasing will be tied into the non-OTAES related development programs. For example, an output is shown on this figure after ground-to-ground optical communications system tests to a suggested parallel study cited as Contract A. Other experiments will have similar inputs to this same study. This Contract A output will serve as a portion of the prerequisite technology which precedes the preliminary design of the OTAES experiment. Again it should be clearly stated that non-OTAES ground programs will involve only major milestone definition.

The result of Part II will be a detailed survey of the optical technology needs of the coming space years and an integrated development program that will indicate an overall direction for NASA planning in optical technology.

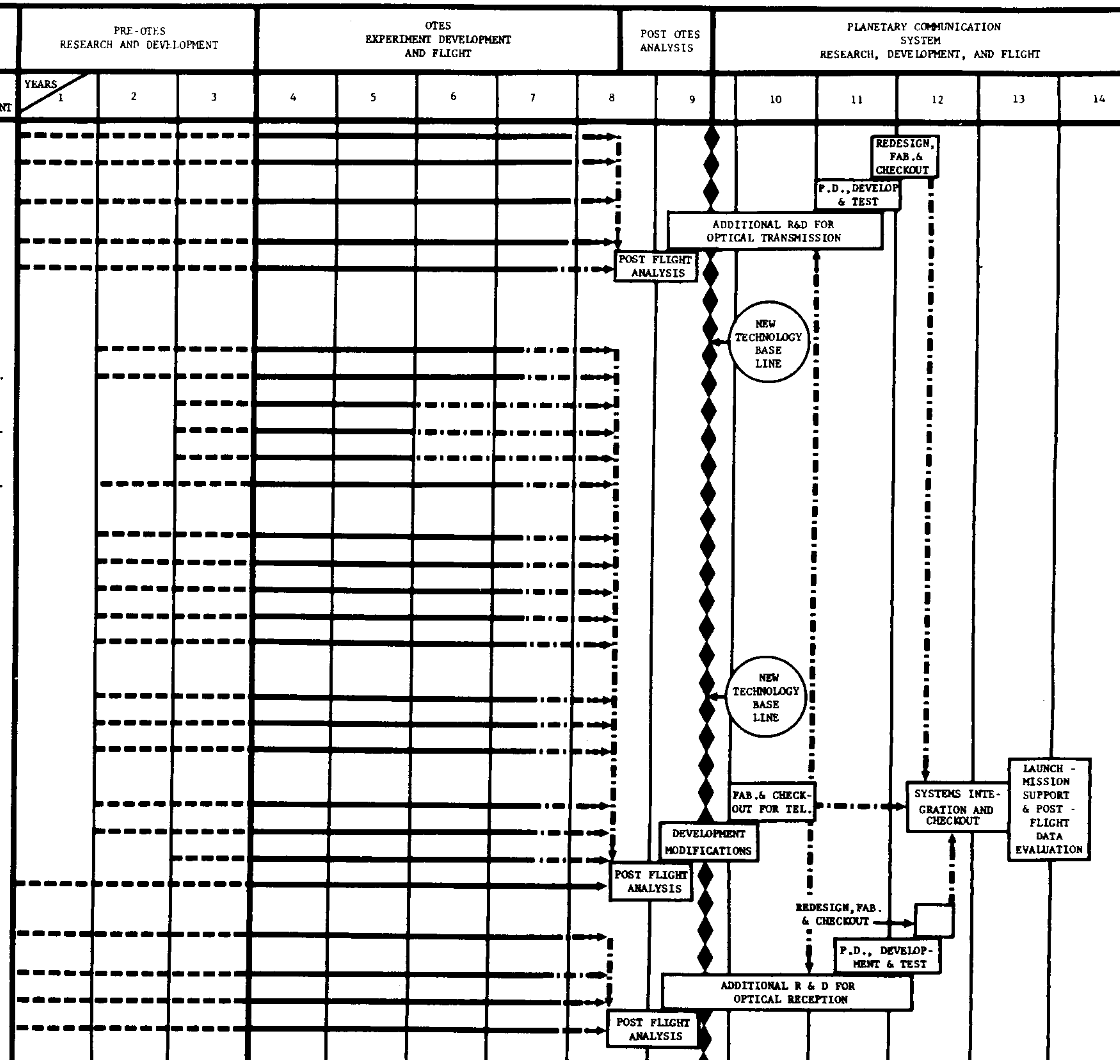
2.0 OTAES EXPERIMENTS

A portion of the Part II study will be increased definition of the recommended OTAES experiments and an investigation for new candidate experiments. These are the objectives of this Task.

2.1 New Experiment Development

One fundamental objective of the OTAES study was to define, justify, and conceptually design optical technology experiments to be conducted in earth orbit. During Part I of this study, fifteen experiments were recommended as candidate flight experiments. The technology development under consideration during this study covered a broad and diverse spectrum of disciplines. This fact, coupled with the limited duration of the Part I study, indicates that a number of candidate experiments might exist which have not yet been recognized. Therefore, it is proposed that a continuing effort be directed toward identifying these experiments.

TECHNOLOGY AREAS	RELATED EXPERIMENTS AND GROUND DEVELOPMENT		
	OTES EXPERIMENTS	OTES RELATED GROUND DEVELOPMENT	OTHER GROUND DEVELOPMENT
I. OPTICAL TRANSMISSION			
A. PATH CHARACTERISTICS AND LINK DEGRADATION	1,2,3,4,5,8,9	B	REQUIRED
B. MEANS OF TRANSMISSION	1,2,3,4,5,6,7 8,9	B	REQUIRED
C. SPACE QUALIFIED SUPPORTING COMPONENTS	1,2,3,4,5,6,7 8,9		REQUIRED
D. OPTIMAL TRANSMITTING FREQUENCIES	1,2,3,4,8,9		REQUIRED
E. INFORMATION TRANSMISSION RATE	1,2,3,4		REQUIRED
II. SUPPORTING TELESCOPE TECHNOLOGY			
A. OPTICAL SUB-SYSTEMS			
1. MATERIALS	10,11,15,16	G	REQUIRED
2. MIRROR FIGURE CONTROL	10,11,15	A,M	NOT REQD.
3. CONTAMINATION	16	G	REQUIRED
4. SURFACE DEGRADATION	16	G	NOT REQD.
5. MIRROR COATING	16	G	REQUIRED
6. THIN MIRROR EVALUATION	10,15,16	G	NOT REQD.
B. TELESCOPE STRUCTURE & MECHANISMS			
1. PASSIVE THERMAL CONTROL	10,11,15	A,M,N	REQUIRED
2. SMALL DISPLACEMENT ACTUATORS	10,12,14,15	A,J,M,N	REQUIRED
3. ALIGNMENT SENSORS	10,11,15	A,J,M,N	REQUIRED
4. FOCUS SENSORS	10,11,15	A,J,M,N	REQUIRED
5. REMOTE ALIGNMENT PROCEDURES	10,11,15	A,J,M,N	REQUIRED
C. CONTROL AND STABILIZATION			
1. POINTING AND TRACKING	5,6,7	B,E,H	REQUIRED
2. POINT AHEAD	6		REQUIRED
3. ACQUISITION	5,7	B,H	REQUIRED
D. OPERATIONS			
1. ERECTION AND CHANGE-OVER PROCEDURES	10,11,14,15	A	REQUIRED
2. LOGISTICS	10,11,14,15	C,E,G,N	REQUIRED
3. OPERATING MODES	13	S	REQUIRED
4. LAUNCH ENVIRONMENT	ALL		REQUIRED
III. OPTICAL RECEPTION			
A. TYPE OF RECEIVER	1,2,3,4,5,6, 7,8,9	K,R	REQUIRED
B. MEANS OF DETECTION	1,2,3,4,6,9	K,R	REQUIRED
C. OPTIMAL RECEIVING FREQUENCY	1,2,3,4,8,9	K	REQUIRED
D. SIGNAL PROCESSING	1,2,3,4,6,7 8,9		REQUIRED



NOTES: 1. SEE SECTION 16.0 FOR EXPERIMENT DEVELOPMENT DETAILS.

2. THIS FIGURE IDENTIFIES BUT DOES NOT SCHEDULE OTHER NEEDED GROUND DEVELOPMENT NOT SPECIFICALLY IN SUPPORT OF SPACE EXPERIMENTS.

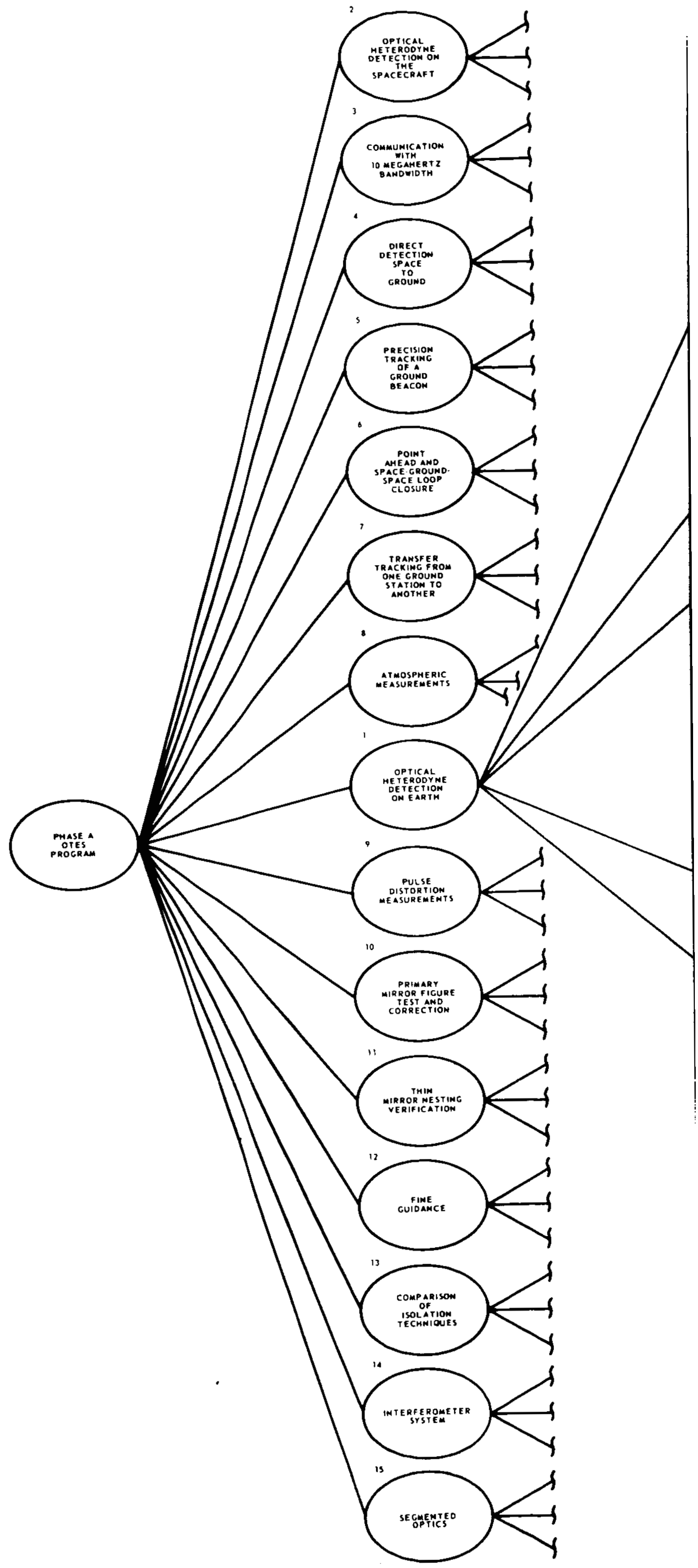
KEY

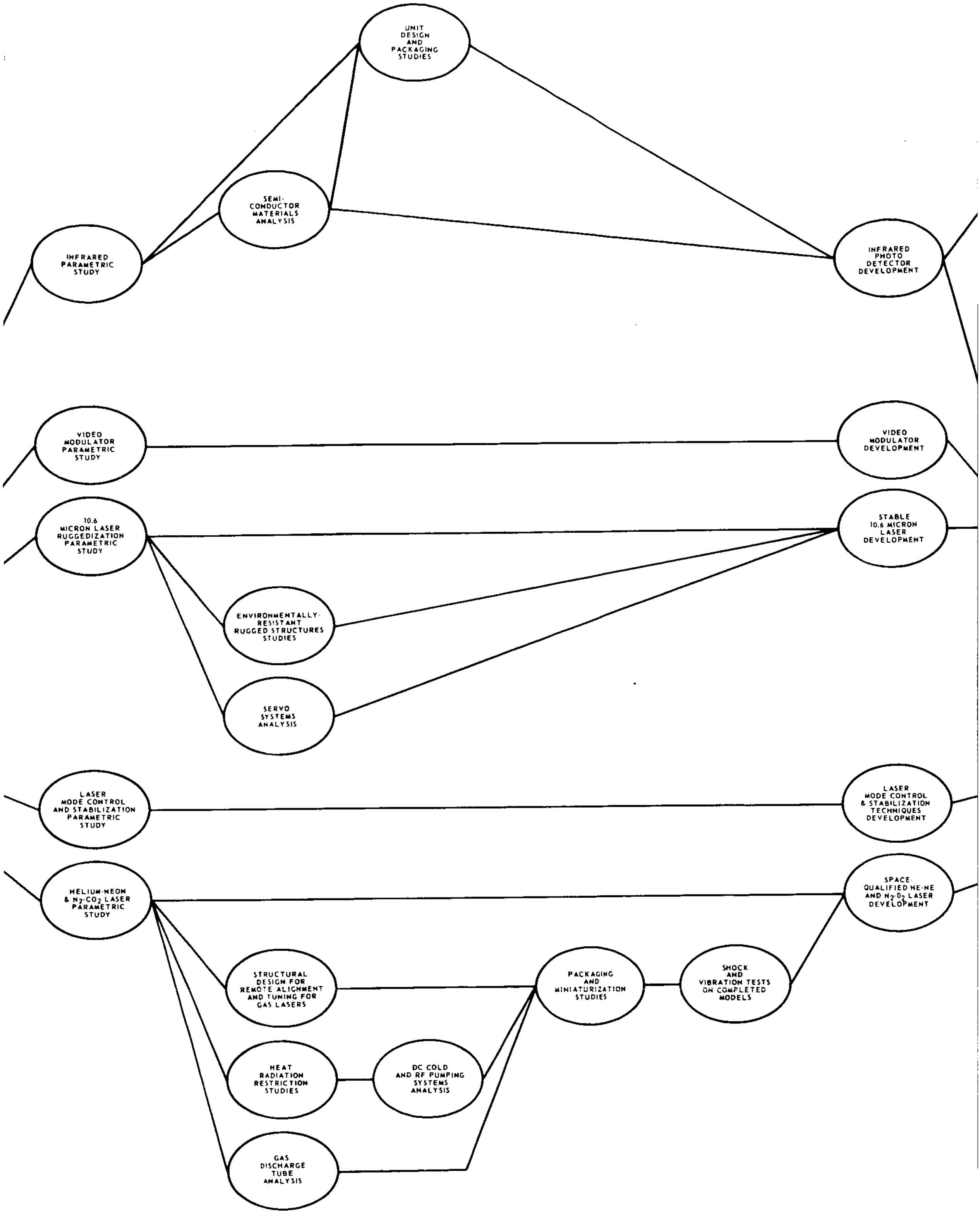
- ━━━━ OTES EXPERIMENT DEVELOPMENT AND FLIGHT
- ━ ━ ━ PRE-OTES RESEARCH AND DEVELOPMENT
- ━ · ━ · GROUND EXPERIMENTS AND DELAY TIME

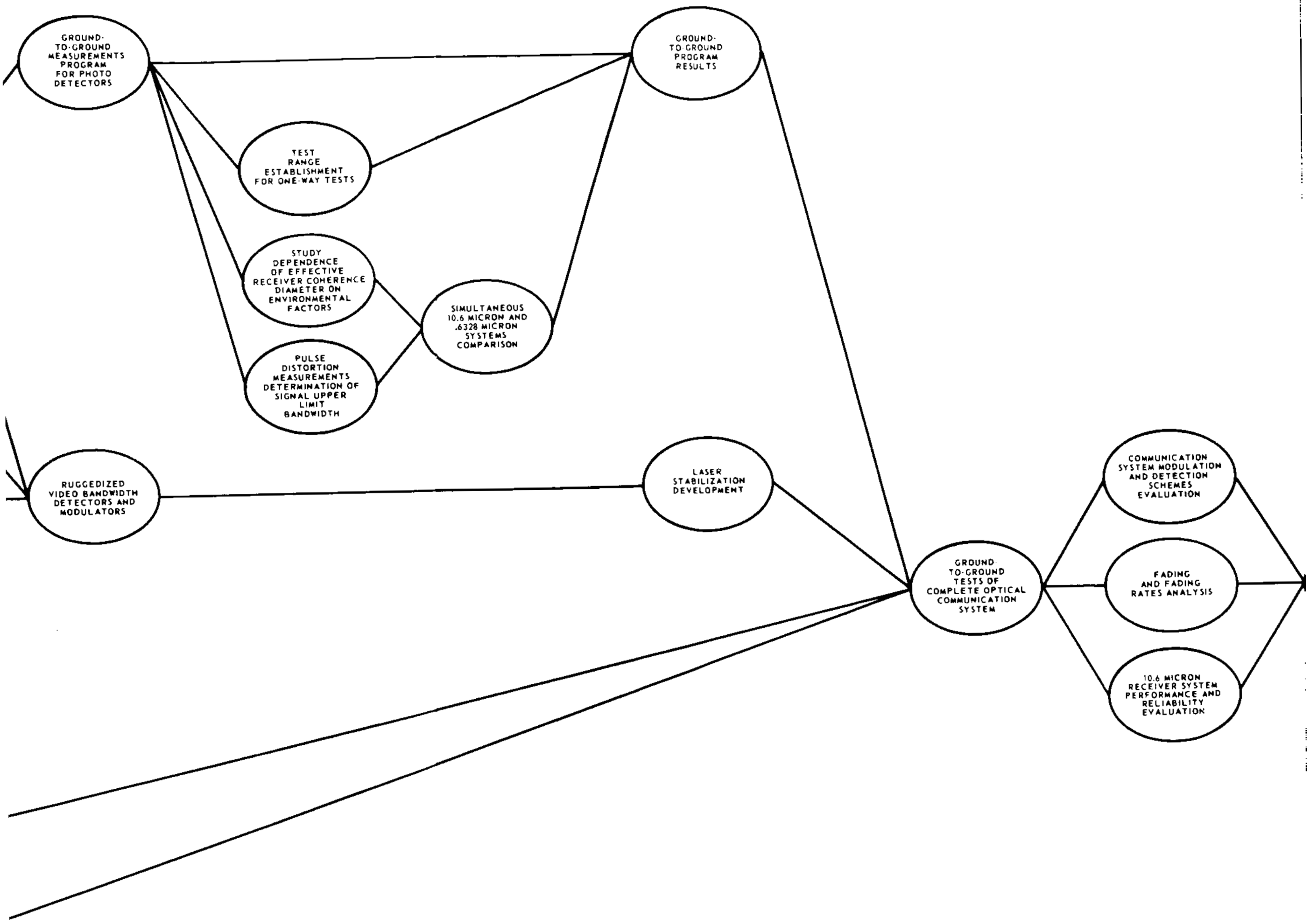
LONG RANGE OPTICAL PROPAGATION TECHNOLOGY DEVELOPMENT MILESTONES

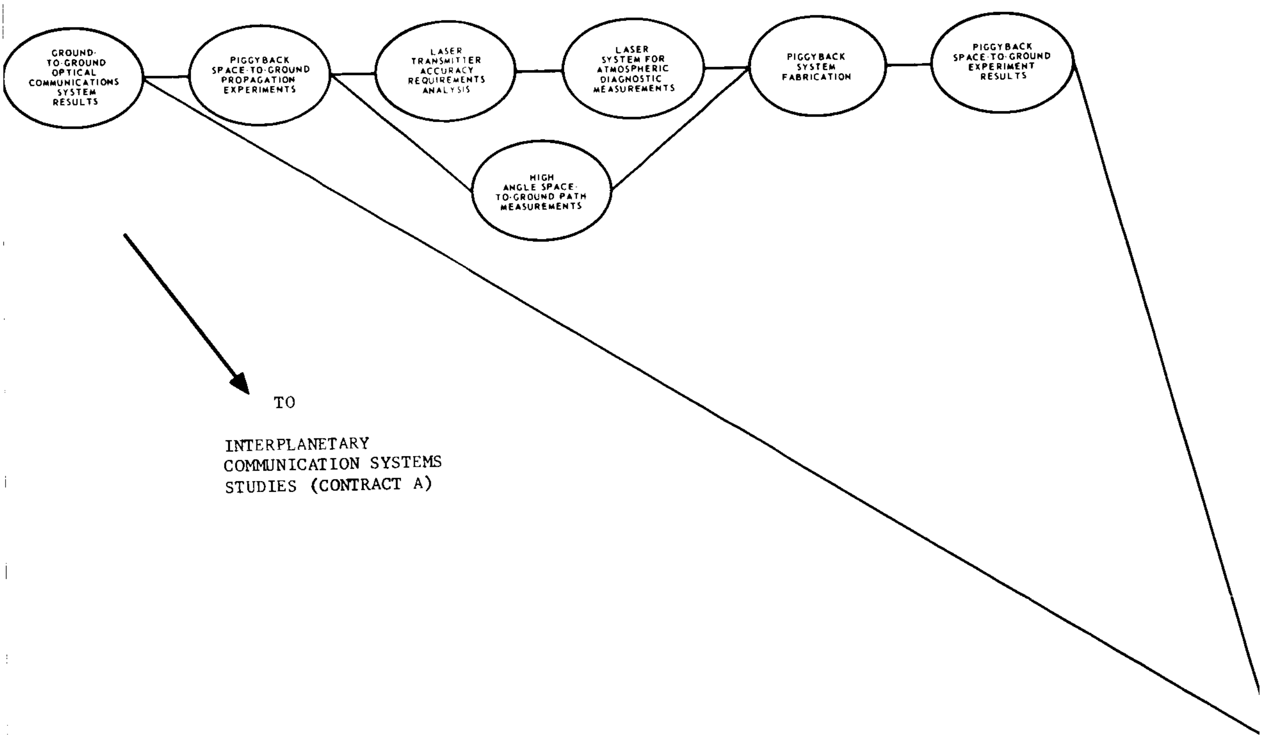
Figure 3. Interplanetary Optical Communication System Development

EXPERIMENTS




UNIT DESIGN AND PACKAGING STUDIES
SEMI-CONDUCTOR MATERIALS ANALYSIS
INFRARED PARAMETRIC STUDY
INFRARED PHOTO DETECTOR DEVELOPMENT
VIDEO MODULATOR PARAMETRIC STUDY
VIDEO MODULATOR DEVELOPMENT
10.6 MICRON LASER RUGGEDIZATION PARAMETRIC STUDY
STABLE 10.6 MICRON LASER DEVELOPMENT
ENVIRONMENTALLY-RESISTANT RUGGED STRUCTURES STUDIES
SERVO SYSTEMS ANALYSIS
LASER MODE CONTROL AND STABILIZATION PARAMETRIC STUDY
LASER MODE CONTROL & STABILIZATION TECHNIQUES DEVELOPMENT
HELIUM-NEON & N_2-CO_2 LASER PARAMETRIC STUDY
SPACE-QUALIFIED HE-NE AND N_2-0_2 LASER DEVELOPMENT
STRUCTURAL DESIGN FOR REMOTE ALIGNMENT AND TUNING FOR GAS LASERS
PACKAGING AND MINIATURIZATION STUDIES
SHOCK AND VIBRATION TESTS ON COMPLETED MODELS
HEAT RADIATION RESTRICTION STUDIES
DC COLD AND RF PUMPING SYSTEMS ANALYSIS
GAS DISCHARGE TUBE ANALYSIS


GROUND-TO-GROUND MEASUREMENTS PROGRAM FOR PHOTO DETECTORS
GROUND-TO-GROUND PROGRAM RESULTS
TEST RANGE ESTABLISHMENT FOR ONE-WAY TESTS
STUDY DEPENDENCE OF EFFECTIVE RECEIVER COHERENCE DIAMETER ON ENVIRONMENTAL FACTORS
SIMULTANEOUS 10.6 MICRON AND .6328 MICRON SYSTEMS COMPARISON
PULSE DISTORTION MEASUREMENTS DETERMINATION OF SIGNAL UPPER LIMIT BANDWIDTH
RUGGEDIZED VIDEO BANDWIDTH DETECTORS AND MODULATORS
LASER STABILIZATION DEVELOPMENT
GROUND-TO-GROUND TESTS OF COMPLETE OPTICAL COMMUNICATION SYSTEM
COMMUNICATION SYSTEM MODULATION AND DETECTION SCHEMES EVALUATION
FADING AND FADING RATES ANALYSIS
10.6 MICRON RECEIVER SYSTEM PERFORMANCE AND RELIABILITY EVALUATION


GROUND-TO-GROUND OPTICAL COMMUNICATIONS SYSTEM RESULTS
PIGGYBACK SPACE-TO-GROUND PROPAGATION EXPERIMENTS
LASER TRANSMITTER ACCURACY REQUIREMENTS ANALYSIS
LASER SYSTEM FOR ATMOSPHERIC DIAGNOSTIC MEASUREMENTS
PIGGYBACK SYSTEM FABRICATION
PIGGYBACK SPACE-TO-GROUND EXPERIMENT RESULTS
HIGH ANGLE SPACE-TO-GROUND PATH MEASUREMENTS
TO
INTERPLANETARY COMMUNICATION SYSTEMS STUDIES (CONTRACT A)

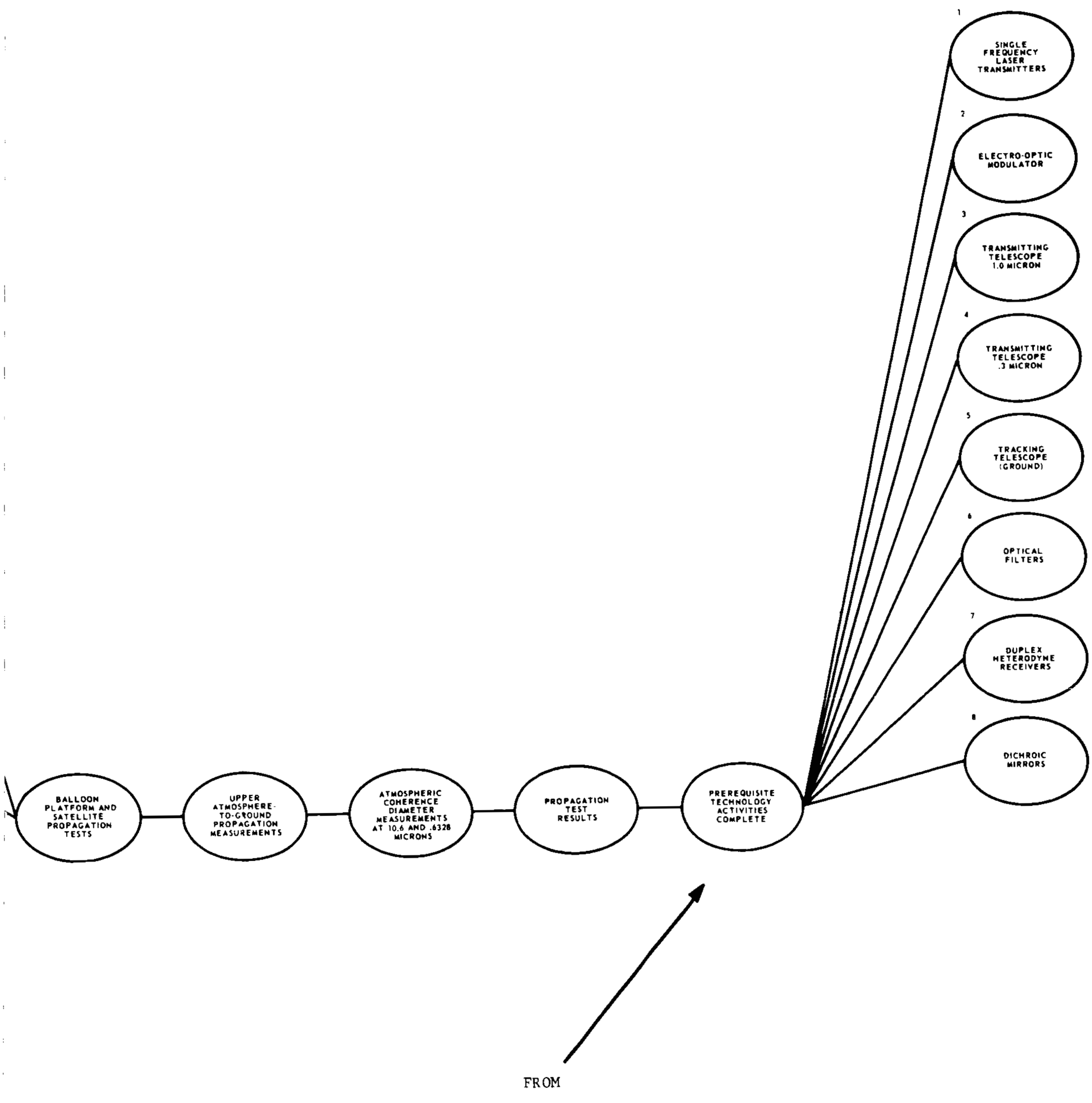


Figure 4. Details of Prerequisite Technology for Optical Heterodyne Detection Experiment

During this study experiments were justified in terms of three criteria. These were: contribution and need, need for space testing, and feasibility. New experiments developed during this phase must also meet these criteria. Those which do, if any, will then be conceptually developed to a level consistent with the integration effort.

During Part I several potential areas from which experiments might evolve were identified. These areas include far infrared interference spectroscopy, ground resolution from earth orbit, space photography, and degradation of optical materials and coatings. Emphasis during Part II will be directed toward identifying experiments in these specific technology areas.

2.2 Recommended Experiments Review

Fifteen experiments were developed to the recommended status during Part I. The level of investigation basically involved two parts: justification, and conceptual design. During Part II the recommended experiments will be developed further in both of these areas.

Further justification will be accomplished by directing more effort toward a quantitative justification of the need for space testing. That is, where possible, an analytical treatment will be performed which will indicate the degradation of experimental results when performed on the earth.

Experiment conceptual design will be emphasised further with the intent of developing five specific areas in greater detail. These are: a review of design alternatives, development of reliability data, increased definition of operational procedures, improved definition of supporting technology development, and the development of preliminary costing data.

During Part I the experiment concepts evolved through several design paths. It is not obvious that all alternatives were considered. Therefore, an important part of this sub-task will be to review each experiment to determine if other attractive design alternatives exist.

An important part of Part II study will be a comparative reliability analysis of the means for implementing the recommended experiments. In order for this analysis to be meaningful, reliability data is required for each experiment. Thus an important portion of the Part II experiment review will be the development of reliability data for the experiment components, subassemblies, and assemblies.

During Part I a rudimentary operational procedure was developed for each experiment. These were used to develop preliminary time-lines and to assess the criticality of astronaut participation. During Part II it is proposed that these operational procedures will be developed in considerably more detail in order to support not only the time line and criticality analyses, but also to develop the control and display requirements (sub-task 4.4).

A prerequisite technology digest was developed for each experiment during the Part I study. The development milestones were identified and scheduled.

During Part II of the study this prerequisite technology will be given the next level of definition, which would include cost estimates. This definition will also include a more precise discussion of the test and development requirements.

Because the essence of the OTAES program is space experiments, the technology development plan will centralize the total experiment analysis in one section. Not only will the sequential development activities be identified, but experiment costs will also be derived. The costs of the experiment sub-systems will be utilized as the estimating base for the projection of individual experiment costs. These costs will provide the data required to analyze the economic trade-off alternatives to be performed in the mission cost alternatives analysis (see sub-task 5.2). These alternatives will include key subsystem development alternatives. For example, the Direct Detection experiment might be accomplished by successive ground and airborne tests or, alternatively, immediate piggyback orbital testing. Costs are an important factor in choosing between these alternatives. By marrying the experiment costs from this section with the supporting spacecraft costs (sub-task 5.1) the following alternatives can be evaluated in the mission cost analysis (sub-task 5.2): (a) Experiment costs when flown as individual experiments in fragmented programs (b) Experiment costs when flown collectively on other than an OTAES vehicle (c) Experiment costs when flown collectively on any of the OTAES candidate mission approaches.

The individual experiment cost projections will be founded on a "building blocks" approach. This identical approach will be utilized in developing the supporting spacecraft costs (sub-task 5.1). The basic estimating level in this analysis will be the sub-system as major assembly. The data collected at this level will then be summarized at the systems level. Additional information will then be summarized at the systems level and culminate in summary at the total individual experiment level. This approach ensures a system of projections that are comprehensive and consistent with the cost projections for the supporting spacecraft analysis. The resulting experiment cost projections will be utilized further in the mission cost analysis (sub-task 5.2).

In summary, the Recommended Experiments Review sub-task will emphasize the following areas:

a. quantitative experiment justification

b. design alternatives review

c. reliability data

d. operational procedures

e. prerequisite technology development

f. costs

3.0 EXPERIMENT INTEGRATION

3.1 Comparative Reliability Analysis

The purpose of this sub-task will be to obtain relative probability of success measures for the alternate choices of conceptual designs and mission profiles under consideration. Specific elements of these probability estimates will be compared with probability estimates for accomplishing the technological experiment objectives directly as a part of an application development. Such a comparison will be quantitative where it is possible to make it so.

In this work, reliability will be expressed in terms of the performance of the experiments. It should be borne in mind that if a component will not function in space as predicted for some reason, the test may be a success if NASA learns why it would not work and develops the technology necessary to predict what will work. It is important, therefore, to distinguish between the success of the experiment and the success of the component.

Due consideration will be given to the need for backup modes of operation in order to assure the return of useful technological data. Risk is almost by definition a part of a technology program because after the risk is removed the further developmental work becomes usually an applications rather than a technology program. It is both appropriate and desirable, therefore, to include in the technology tests elements having substantial uncertainty of performing as predicted. Under these circumstances it is important that there should be backup equipment and experiments so arranged that the failure of one element does not jeopardize success in accomplishing tests of other elements. The reliability of alternative backup arrangements for grouped experiments will be compared with the reliability of experiments flown singly.

In providing the backup experiment configurations, the presence of a man to evaluate test results, even failures, is of great value. Since the objective is to develop understanding of the technology, it is not enough to know that a component failed or did not fail; it is necessary to establish the nature of the failure, the limits of the parameters in which operations would produce failure, and, hopefully, the limits in which success might have been achieved. To obtain this kind of information in an unmanned flight would require the accurate prediction of all failure modes as well as instrumentation to detect them.

The effect of man in this context on the reliability will be investigated. Within this philosophy reliability estimates will be formulated early enough to influence other tasks during the study.

In performing this sub-task, system and components will be assessed for relative reliability merits, trade-offs, and indicated modifications. These analyses will emphasize: (a) space environment effects (radiation, thermal, vacuum, micrometeoroid), (b) component useful life characteristics (wear out), (c) parts and materials applications (multi-application reliability), (d) failure modes and effects (in-flight), (e) failure detection (in-flight), (f) failure correction, repair, or compensation (in-flight), (g) parts and circuit or channel redundancy applications and trade-offs.

Reliability assessment may be described as the determination of the following probabilities: (a) the probability of malfunction of any mission-critical equipment during countdown, boost, and orbital operations over a two-year period, (b) the probability of malfunctions causing specific functions to fail, specific experiments to fail, false failure indications, and two or more parts (functions) to fail, (c) the conditional probabilities (given a malfunction has occurred) of failure detection, failure correction (or compensation), other component damage, experiment failure, or mission failure.

This reliability assessment will be based on the application of the Chrysler simulation model SDS-902, "Reliability Model Design Standard" for determining system reliability.

By implication, the computer will receive information about conditions that would cause a spacecraft malfunction. Thus, from a simulated part failure, the computer could trace the effects of the malfunction down through the system, list all intermediate effects, take into account the time-of-flight effects, and ultimately assess the final effect on the spacecraft. The computer can trace back from an effect to a part failure or even to several simultaneous part failures. In addition to providing a means of calculating reliability, the CCSD computational model provides an automatic failure effects analysis, reliability as a function of flight time, probable failure modes, probable time to failure, an easy means of evaluating design changes, and the priority of testing.

Maximization of system effectiveness will be approached from alternate solution evaluations in the area of preferred sequencing of experiments, and in the area of reliability implications of telescope/experiment assignments.

Preferred sequencing of experiments will result from the modeling of malfunction-decision cycles. Figure 5 illustrates a typical computer malfunction-decision cycle which would be used to analyze this sequence of events. For example, the first junction in the cycle could be a decision to "repair". The computer will proceed throuh the repair cycle and then move to a new sequence of experiments after a favorable checkout has been achieved. Figure 6 demonstrates how data from the computer simulation may be analyzed. Here, particular sequences are compared in order to determine which provides the highest cumulative expected value for achieving a percentage of events. 'Expected value' is defined as the inherent scientific value of the events at expressed numerically and multiplied by the estimated probability of achieving the event. For this hypothetical case, sequence 15 provides the highest cumulative value throughout the first 25 per cent of the events. Sequence 16 provides the highest final cumulative value for the first 50 per cent of the events achieved. However, mission success might require 100 per cent of e events achieved. This would make sequence 17, which provides highest final value for 100 per cent of the events, the optimum sequence.

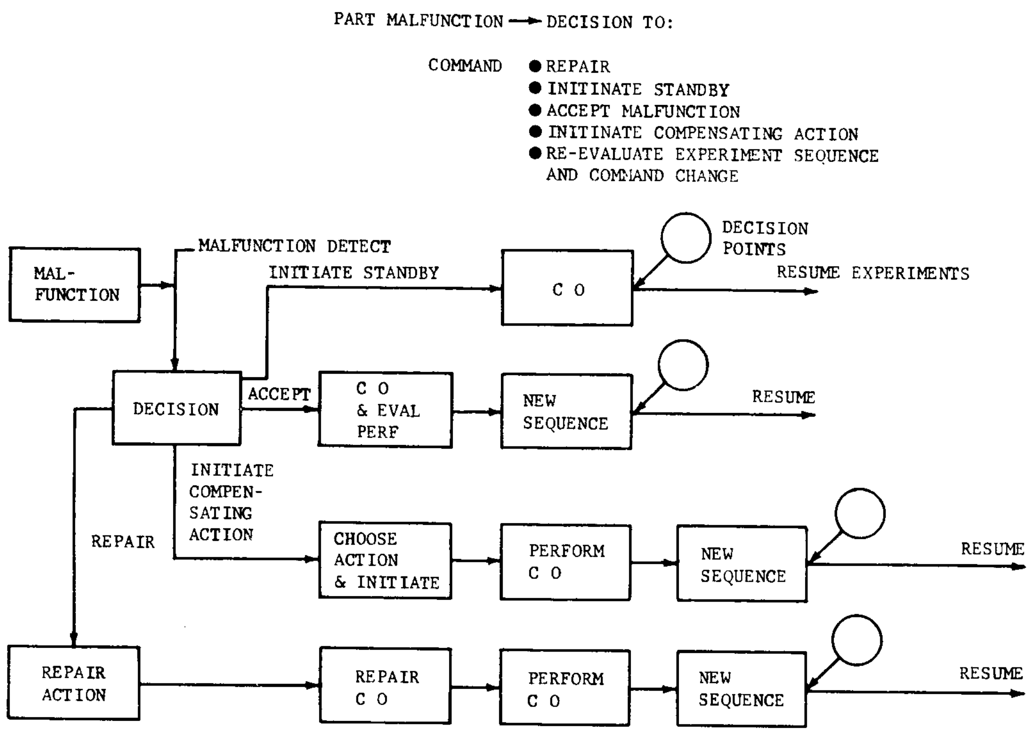


Figure 5. Decision Points Flow Diagram

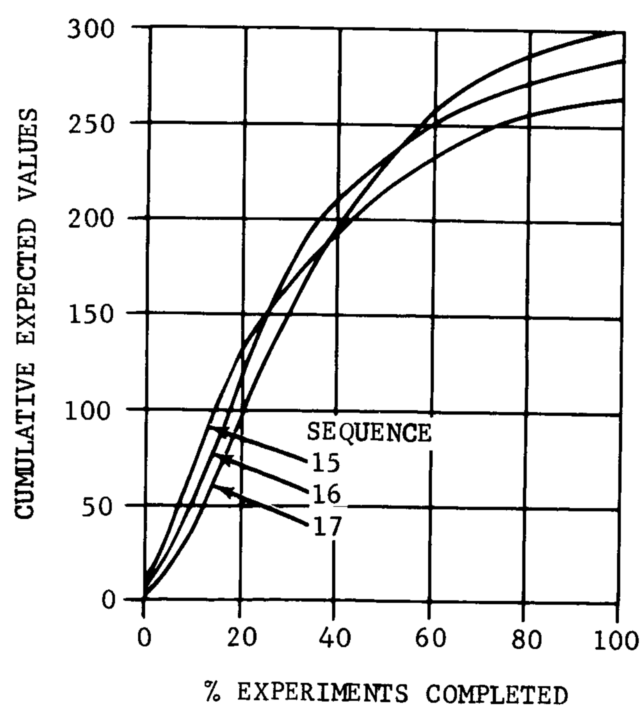


Figure 6. Expected Values

Thus far in this study, experiments have been arranged into groups subject to compatibility requirements from the standpoint of manning requirements, orbital requirements, and equipment commonality. In this portion of the study, the effect on the overall experiment group success probabilities will be assessed to determine the influence of the addition or exclusion of the individual experiments relative to a particular group. This analysis may dictate some redundant experiment components in order to meet overall system performance requirements.

The third reliability evaluation area involves system parameter selections in terms of subsystem alternatives and in terms of mission profile alternatives.

For example, the spaceborne laser transmitter wavelength will depend on the performance of available lasers. Heterodyne detection systems operating at 0.488 microns would require use of a spaceborne argon laser. The high output power capability of argon lasers make them attractive. However, in addition to their high threshold power, argon lasers currently have more failure modes and lower reliability figures than Helium-Neon lasers.

3.2 Manned Operations

Flight crew involvement will be critical to the operational success or failure of many OTAES spacecraft stationkeeping, crew sustenance, and experiment instrumentation systems. In this connection, a synthesis effort will be performed of manned OTAES stationkeeping and experiment functions. These functions (concurrent, sequential, and interrelated) will be integrated into a crew activity time line, which will include intravehicular and extravehicular crew performance, workload availability, timesharing, and changeover. The activity time line will also be detailed enough to serve as a basis for preliminary spacecraft system functional specifications.

One fundamental objective of this task will be to assess the criticality of manned operations. Much of this was done during Part I; however, a continued analysis of task alternatives is necessary to determine the full extent of manned participation. This effort is closely coordinated with the operational analysis for each experiment in sub-task 2.2. This evaluation of manned operations has a direct bearing on the mode of operation and hence on the design approach of any particular experiment. For instance, the choice of shirt sleeve versus EVA operation will influence the conceptual configurations as in the case of the interferometer. Often this choice is influenced by other subsystem factors. For example, shirt sleeve accessibility to telescopes could effect contamination (ECS) and thermal balance (Thermal Control). This approach must also provide data to determine whether the human function places constraints upon experiment operations, such as inducing motions which can degrade OTAES fine pointing experiments. A disturbance analysis (sub-task 4.2) is required. In this regard, body segment motions, associated with representative human functions, will be specified to support this disturbances analysis. The body segments under consideration will include the head, upper torso, lower torso, arms, forearms, hands, thighs, legs, and feet. The body segment motions will be described notationally, utilizing a tri-planar 360°

angular coordinate reference system.(1) (2) Figure 7 illustrates, as an example, a crewman's arm motion, occurring during a proposed 12-hour periodic environmental control system CO_2 absorber filter replacement within the Apollo Command Module. The notations in the illustration, such as "FEV 100°", refer to the plane or planes in which the motion occurs (frontal, sagittal or transversal) direction and extent of the motion, and the type of motion (vection, rotation or torsion).

3.3 Ground Stations

The purpose of this sub-task will be to assess the OTAES ground station requirements in terms of mission performance, operational complexities, development time and technological risks, and reliability. A conceptual design will be presented including subsystems and operational instrumentation, power profile, communications, data handling, and transmission systems.

OTAES ground station requirements will be analyzed to: (a) formulate the station operations and integration concept, (b) define data processing requirements, (c) define the RF command and telemetry link requirements. Parametric OTAES ground station requirements will be compared with existing tracking systems and spaceground systems. These requirements will principally derive from the specialized optical ground equipment and the RF tracking system required to acquire the satellite and provide coarse pointing information to assist ground laser acquisition.

Performance of this sub-task will include: (a) specification of required modifications to ground systems, (b) the conceptual design of the display and control area, (c) changeover procedures from OTAES ground station to ground station and command and control procedures, and (d) integration of the radio frequency and optical links.

3.4 Mission Profiles

During Part I of this study many candidate missions were parametrically analyzed. As a result of this analysis, four missions were recommended for implementation of the OTAES experimental program. The purpose of this sub-task is to define these missions in more detail, evaluate each relative to the others, and define the orbital and launch operations associated with each. The individual sub-tasks are briefly described below.

---

(1) Roebuck, J. A., Kinesiology in Engineering, Paper presented at Kinesiology Council Convention, American Association for Health, Physical Education and Recreation, March 21, 1966.

(2) Molesko, N. M., A Collection of Papers on Space Suits and Human Performance, Chrysler Corporation Space Division, REL-HFG-65-1, N66-17386, August 16, 1965, p. 10-1.

		BODY SEGMENT MOVEMENT					
	HUMAN FUNCTION	RIGHT ARM		RIGHT FOREARM		RIGHT HAND	
		MOTION	FORCE	MOTION	FORCE	MOTION	FORCE
Step	Activity: Periodic environmental control system CO_2 absorber filter removal from storage. Crewman in constant wear garment and sandals under shirtsleeve conditions.						
6	Position tool in first camlock connector on CO_2 filter storage container lid						
	Forearm/hand motion			FEV 100°			
	Upper arm/forearm/hand motion	TIV 30°					
	Upper arm/forearm/hand motion	FEV 80°					
	Upper arm/forearm/hand motion	TIV 80°					
	Upper arm/foreman/hand motion	SIV 20°					
7	Rotate open first camlock connector						
	Upper arm/forearm/hand motion	SET 120°	20 in-oz				
	Upper arm/forearm/hand motion	SIT 120°					
8	Reposition tool in second camlock connector on CO_2 filter storage container lid.						
	Upper arm/forearm/hand motion	FIV 3°					

LEGEND

FEV = FRONT - E - VECTION
TIV = TRANS - E - VECTION
SIV = SAG - IN - VECTION
SET = SAG - E - VECTION
SIT = SAG - IN - VECTION
FIV = FRONT - IN - VECTION

INDICATES MOTION OF DISTAL BODY SEGMENT BEING INCLUDED IN MOTION OF PROXIMAL BODY SEGMENT

Figure 7. Crew Function and Associated Body Segment Movements During a Proposed OTAES Mission

3.4.1 Mission Evaluation

It is the purpose of this sub-task to perform preliminary trade-off analyses and over-all evaluation from which preferred rankings of the missions can be determined. Mostly, this will involve qualitative analysis based on results from other task areas, including costs, reliability, fulfillment of the scientific objectives, and optimum use of man.

3.4.2 Environmental Definition

During Part I of this study, many parametric studies of the space environment were made. It is the purpose of this sub-task to define in detail and catalog for each of the missions those environmental parameters which have bearing on performance of the experiments and manned operations. This includes radiation, day/night profiles, occultation of experiment field of view, and slew and range rates for the earth-oriented experiments.

3.4.3 Orbital Operations

The purpose of this sub-task is to derive, describe, and tabulate all operational modes from orbit injection to mission completion. This will include sequence of events description with each major event marked and approximate times given. This will be done for each of the recommended missions.

The results of this task will include a detailed description of solar acquisition, microwave acquisition, ground station acquisition, star acquisition, rendezvous, docking, equipment deployment, and stationkeeping events, where applicable, for each of the four missions.

3.4.4 Launch Operations

The purpose of this sub-task is to determine and record the launch requirements and boost sequence for each of the four recommended missions. Generally, this information is available and the effort here will involve collecting the data and integrating it with the other mission information.

3.5 Telescope Configurations

The feasibility of certain groups of experiments is critically dependent on detailed integration of the experiments and their supporting subsystems into the spacecraft. The first level of integration involves the definition of the experiments in context with the telescope concepts. This requires that the telescope optical design, structural support design, and telescope subsystem requirements be conceptually designed. The purpose of this sub-task is to define these elements in more detail and integrate the experiments into these concepts.

The increased emphasis on experiment definition, justification, subsystem requirements, and design will have a significant impact on the telescope configurations. The telescope configuration tasks will parallel the experiment efforts and will insure complete integration of the latest experiment information. The four recommended telescope configurations presented in Part I will serve as a foundation for the continuing effort in this phase. Figure 8 is an example of one of these configurations.

The telescope configuration design effort can be divided into four parts; these are the telescope optical equipment and related subsystems, thermal control and stabilization and control analyses, experiment equipment integration with mounting requirements, and supporting structures and mechanisms, (hatches, baffles, telescope wells, gimbals, and launch support systems).

The optical equipment and related subsystems to be conceptually designed in this phase are the primary mirror with its supports, the secondary mirror, which includes material selection and mirror mounting and alignment requirements. The optical support structure must be conceptually designed for rigidity along with dynamic and thermal stability. The optical elements must be selected so as to satisfy the requirements of the appropriate experiments. This must be done by mating the requirements of the Fine Guidance Experiment, for example, with the requirements of the Stellar Interferometer Experiment. Analyses must be developed to determine the effect of launch loads on the mirror surfaces.

A preliminary thermal analysis will be conducted to ensure that the mirror figure and alignment will not be degraded by thermal distortion. The stabilization and control of the telescopes, independent of the Isolation Comparison Experiment, will be defined, and analyses will be performed to determine actuators, slew rate requirements, vibration tolerances, control signals, total movements required, and integration with the experiment control requirements.

The third area of interest in this phase is to integrate the experiment equipment and to satisfy all experimental equipment environment requirements. Preliminary layout work will be improved to reflect refinement in experiment equipment. Mounting criteria will be firmed and an optical bench will be designed to provide proper alignment and placement of equipment.

The structure that maintains alignment of the 0.3 m telescope with the 1.0 m telescope to which it is attached is a critical area that requires more detailed analyses. Stress analysis, dynamics analysis, and thermal analysis will be performed to ensure that alignment tolerances are maintained. The elimination or addition of experiments to the existing telescope configurations will be incorporated. This will include a new configuration development of the Fine Guidance, Stellar Interferometer, Segmented Optics, and Isolation Comparison telescope to reflect the elimination of the Stellar Interferometer experiment from two configurations using the above-mentioned telescope.

The experiment telescopes have many supporting systems, which are developed in separate areas that have to be incorporated into the telescope configuration. These systems include baffles, hatches, telescope wells with access requirements, gimbals, launch support structure, and the mechanical, structural, and electrical interfaces with the spacecraft.

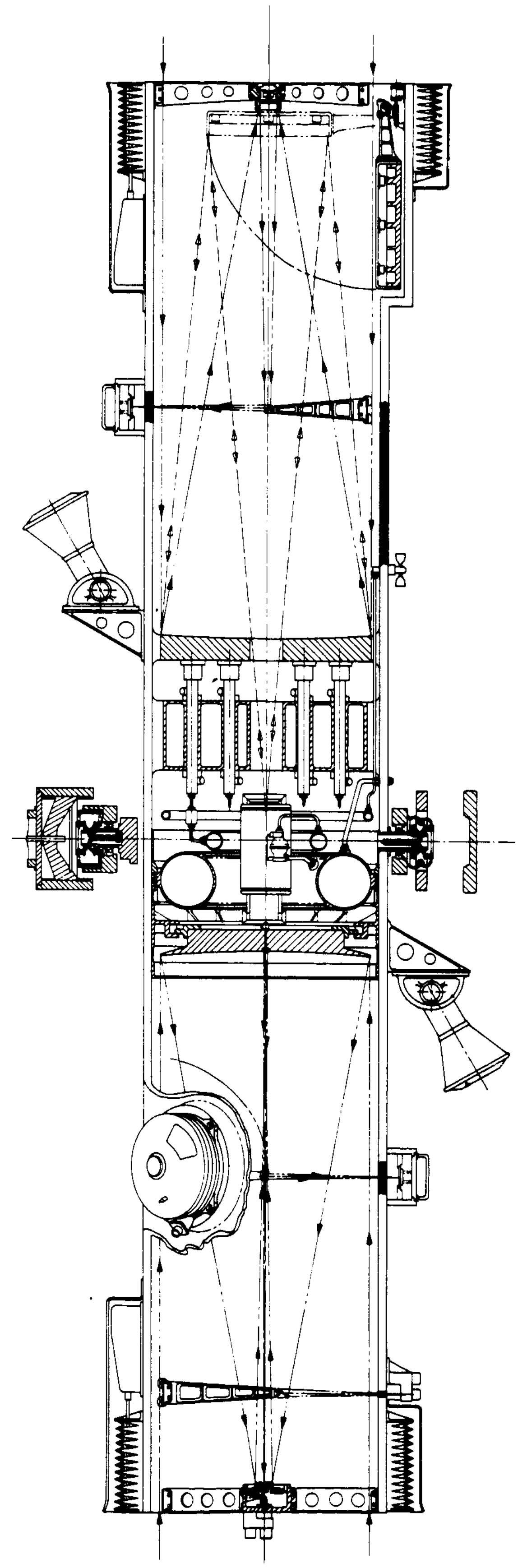


Figure 8. Fine Guidance Telescope

4.0 SPACECRAFT AND SUBSYSTEMS

OTAES experiment implementation as defined in Tasks 2.0 and 3.0 will require supporting spacecraft and subsystems. The integration of experiment groups into spacecraft introduces a variety of technical problems and trade-offs which have direct bearing on both the experiment design and its feasibility of implementation. For that reason conceptual spacecraft and subsystems were developed from which the experiments would be performed. This then allows for investigation of critical technical problems which have a substantial bearing on the experiments. For instance, simulation of the control and stabilization capability for the fine guidance and precision tracking experiments requires definition of spacecraft mass properties. Similarly a meaningful thermal analysis of telescope configurations requires a definition of the surrounding well configuration as well as heat-producing components. Such information is generated in this Task.

4.1 Spacecraft Conceptual Configurations

The spacecraft concepts developed in Part I of the OTAES study were essential in determining the feasibility of experiment implementation. Various alternatives among these concepts were presented as a result of an extensive evaluation of different experiment groups and mission profiles.

The experiments, and related grouping concepts that evolved through analysis as being justified for testing in space, become the heart of the OTAES spacecraft. Four spacecraft concepts were presented as a result of the Part I study. One of these concepts (depicted in Figure 9) is designed to fulfill all presently active OTAES experiments. This configuration makes use of existing Apollo hardware. This will be a definite advantage for early time frame launch considerations.

As OTAES missions are developed further in Part II of the study, and a more detailed integration of experiments is achieved, all experiment and spacecraft subsystems such as environmental control, power, thermal, stabilization and control, communication and data handling, and crew accessories will be conceptually designed.

This study will also include the results of the mass properties of the selected concepts as well as the dynamic response analysis of the integrated experiment telescopes. The interfaces between all subsystems and spacecraft structure will be defined. Conceptual details of all spacecraft and experiment mechanisms such as appendage releases, Solar panel drives, hatches and crew accessories will be presented.

4.1.1 Spacecraft Conceptual Designs

The spacecraft concepts presented in the Part I final report will receive considerably more depth of study as Part II of the program progresses. This will then give sufficient information to evaluate competing approaches to performing OTAES experiments. These configurations will be developed with more structural detail in addition to detailed subsystem definition. As the OTAES

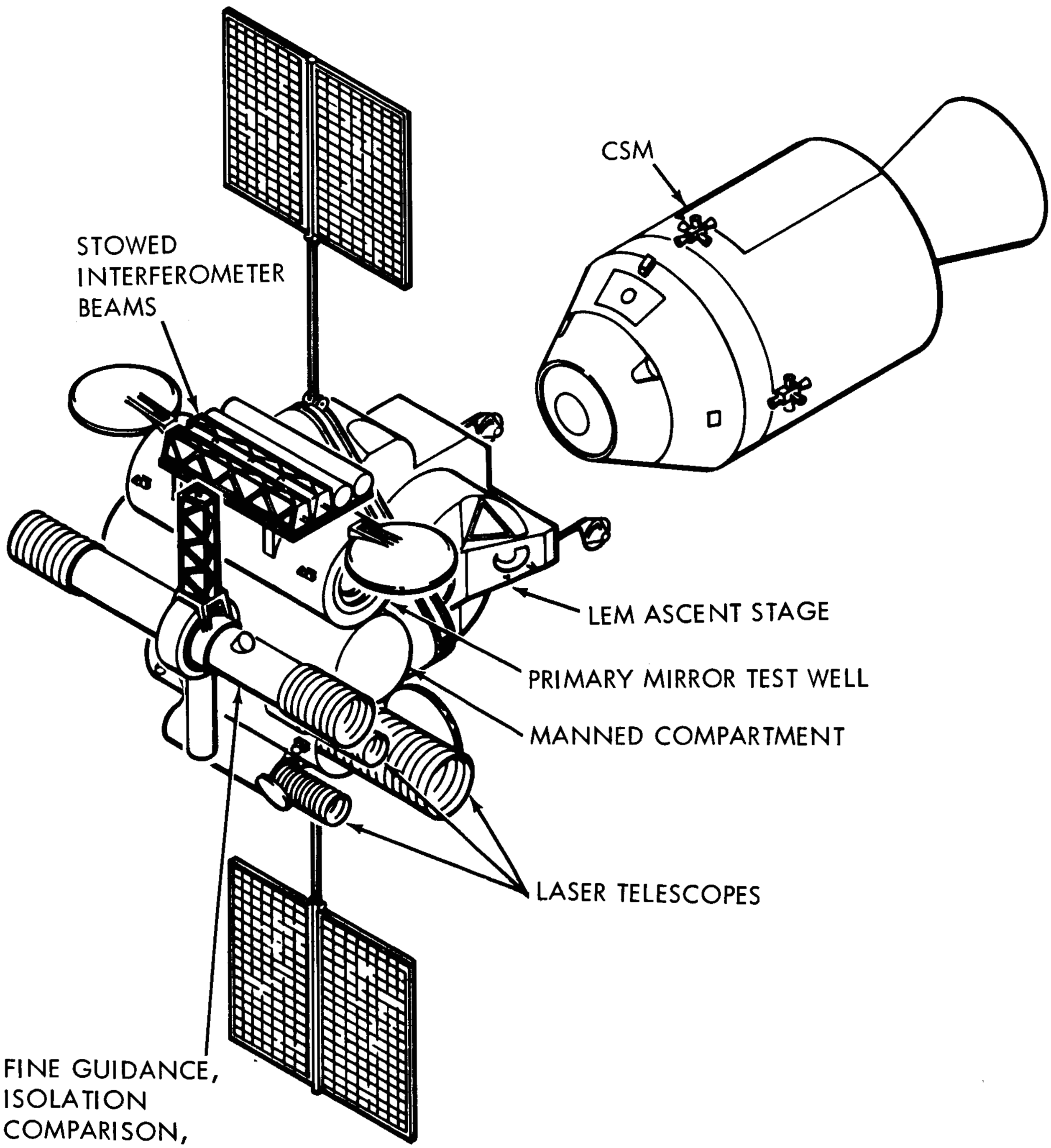


Figure 9. Spacecraft Configuration Making Use of Existing Apollo Hardware

mission becomes more definitive, the environmental control systems, for example, will be studied for compatibility with the mission. The results will be integrated into conceptual designs of the necessary ECS hardware, which, in turn, will affect the over-all spacecraft configuration.

Another area which will receive effort will be in the area of solar paddle configuration, location and orientation. Spacecraft shadowing studies will be performed to insure that the utilization of paddle area is realistically established.

4.1.2 Structural and Mechanical Design

The operating requirements of the laser telescopes impose very stringent requirements on the optical alignment integrity. It is essential that the experiment optical components, as well as one telescope to the other, maintain precise alignment. The structural areas interfacing the experiment components and telescopes will be conceptually designed and analyzed to determine if the proposed techniques are feasible for maintaining the required optical alignment.

The necessary mechanical conceptual designs in support of the various experiments and spacecraft subsystems will also be a part of this Task. These designs are necessary, for example, in order to support the task concerned with spacecraft stabilization and control.

Pressurized spacecraft concepts will require further development of the various hatch designs presented in Part I of this study.

The Solar paddles required will receive more attention in the areas of deployment and release mechanisms. Since the requirement exists for continuous Solar orientation of the paddles on some configurations, drive mechanisms for performing this function will also be investigated.

4.1.3 Mass Properties, Stress and Loads Analysis

The mass properties output will consist of spacecraft moments of inertia about the pitch, yaw, and roll axes, the total weight, and the center of gravity about three axis. The output of this task will allow for further simulation of the control and stabilization systems supporting the fine guidance and precision tracking experiments. This information will also be used in the mission analyses task to insure, among other things, vehicle compatibility.

The stress and thermal stress analyses will include a review of all materials used in the spacecraft for compatibility with the loads and space environment. Inputs to this task will be derived from the thermal analysis and conceptual design drawings.

In order to enable assessment of the feasibility of the structural system and to obtain an estimation of the structural weight, a stress analysis will be performed on all structural components in the spacecraft that are subject to launch loads. All pressurized portions of the spacecraft will be analyzed for external or internal pressurization. The deformations of all deflection limited components, such as optical devices or structures supporting optical devices which deflect under thermal gradients, will be calculated.

All structures will be made resistant to the effects of space radiation, hard vacuum conditions, and micrometeorite impingement. Launch and orbital docking loads on the spacecraft will be defined during this part of the study.

4.2 Control and Stabilization

It has been shown in Part I of this study that telescope stability is a critical area for many of the experiments. Further, it has been shown that telescope stability is critically dependent on the total spacecraft environment and that the telescope control systems, the spacecraft control system, and the fine guidance loops are interdependent. And while it has been shown that the experiments taken individually are feasible, it has not been proved that this is true when they are taken as groups and integrated into the spacecraft. It is the purpose of this sub-task to synthesize a spacecraft control and stabilization subsystem and do those analyses required to show that, from the standpoint of telescope stability, the experiments are in fact feasible. The individual sub-tasks required to do this are defined below.

4.2.1 Experimental Requirements Analysis

Generally, the experiments are defined in enough depth to allow the control and stabilization requirements to be determined. Therefore, this sub-task will consist largely in compiling, categorizing and interpreting these requirements, with some further analytical work to be done in particular areas. For example, several experiments, including the Stellar Interferometry experiment, will be performed on the fine guidance telescope. The pointing requirements for this telescope have been determined, and so have the requirements it imposes on the spacecraft stabilization and control subsystem. However, a detailed analysis of the effect of telescope support acceleration on the stability of the interferometric booms may show that spacecraft attitude motion requirements during the interferometer experiment need be tightened.

4.2.2 Subsystems Requirements Analysis

The communications and power subsystems impose requirements on the control and stabilization subsystem. Generally, these requirements are known. The purpose of this sub-task is to determine the extent to which these requirements can be reconciled to the experimental requirements, and to do a trade-off analysis in the power area to determine the weight penalty and effect on spacecraft stability of orienting the solar panels as a function of time to maximize the power output.

4.2.3 Stationkeeping and Orbital Operations Requirements

One function of the control and stabilization subsystem is to provide stationkeeping for those missions requiring it. Also, certain orbital operations such as acquisition and docking maneuvers will impose attitude control requirements. The purpose of this sub-task is to determine for each of the candidate missions the stationkeeping requirements in terms of fuel consumption, synthesize a program for effecting the orbit maintenance impulses, determine the attitude control requirements during each operational phase of the mission, choose a control technique to effect these requirements, and do those analyses required to determine weight penalty associated with each phase.

4.2.4 Momentum Handling Requirements

Several parametric studies to determine external torques and the long term and periodic momentum handling requirements associated with these torques were performed in Part I of this study. The purpose of this sub-task is to compile, for each of the missions, detailed specifications on these requirements.

4.2.5 Control System Synthesis

The purpose of this sub-task is to synthesize an economical (in terms of weight and power) and reliable stabilization and control subsystem to meet the requirements established in the sub-tasks discussed above. Much of the analysis required to do this has already been performed in Part I of the study. Sensors, for example, have been chosen for a baseline configuration. An actuator system, consisting of a two-axis gyro for pitch and yaw and a single-axis gyro for roll control, has been tentatively chosen. However, experimental requirements as currently defined indicate the use of single-axis control gyros, at least for some of the missions. Further analysis will be performed as required to choose actuators for each mission studied in Part II. For example, detailed vibrational analyses may show that the vibration environment associated with high-speed control gyros cannot be tolerated in the optics. If so, reaction wheels would be indicated, which would have important implications in several trade-off areas, as trade-off analyses previously made for control gyros will not hold for reaction wheels.

The reaction-jet system will be synthesized, based on the stationkeeping, orbital maneuvering, and momentum expulsion requirements. Some of the spacecraft to be studied already incorporate reaction-jet systems. For these, the objective will be to determine the modifications that are required. This has been done, for example, for a baseline configuration during Part I of the study. During Part II an RLS subsystem will be synthesized for every mission that is defined.

The control system as a whole will be synthesized by integrating the reaction jet system with the momentum expulsion system and establishing the interface between the experiment telescopes and the spacecraft stabilization and control subsystem. A technique for unloading the momentum storage system will be synthesized.

Power, weight, and size will be determined for the stabilization and control components and detailed for each of the defined missions.

4.2.6 Control System Analysis

The purpose of this sub-task is to do those analyses required to verify performance of the over-all control system during each operational mode. To do this, hand calculations, digital root-locus routines, and analog simulation will be used.

Generally, detailed analysis and simulation will be performed for only one typical mission. Hand calculations to derive gain and control bandwidth requirements and to establish compensation requirements will be performed for each mission that is defined.

4.3 Power System

During Part I competing power generation systems were evaluated for OTAES configurations. As a result, solar cell arrays were recommended as the preferred system. In Part II solar cell arrays will be analyzed in sufficient depth to analyze various experiment sequences in each of the mission profiles developed in sub-task 3.4. To do so, the load profiles will be updated by adjusting experiment and spacecraft power requirements in conjunction with those missions.

4.3.1 Solar Cell Array Analysis

One objective of this sub-task will be to consider the radiation, meteoroid, and thermal environment of each of the recommended missions and relate the environment to performance degradations in the power system.

Another area to be investigated in this sub-task is the effect of shadowing of the panels by the spacecraft or the panels themselves. Among the factors that will be considered in this study are: orbit position, orbit inclinations, panel location, and array type and size.

An important part of this effort will be the interface analysis. Among the interface areas to be analyzed in this sub-task are: the interface between the power system and the experiments, the structure connecting the panels with the spacecraft, the deployment and orientation mechanisms, and the effect of orienting the panels on attitude control. Extremely close coordination will be required between this sub-task and the other spacecraft and experiment tasks.

The major part of this activity will be devoted to the interface between the power system and the experiments. This interface, at the telescope gimbals, has the objective of evolving techniques to get power into the telescopes without transmitting disturbances to the telescope. The results of this analysis will also assist the data handling task since the information flow from the wells is quite similar to the power flow into them.

4.3.2 Power Conditioning and Distribution Analysis

The purpose of this effort will be to define the optimum power distribution network, at the block diagram level, on the basis of the power characteristics required, the physical location of power-using equipment, and the reliability and performance characteristics of the various conversion equipment and design approaches.

Three types of distribution networks will be considered. These are: centralized dc, decentralized dc, and hybrid ac/dc systems. The various attributes of each will be compared and, based upon the results, a single concept recommended for future study. Also included in this sub-task will be conceptual design of the controls for the power systems.

4.3.3 Secondary Battery Analysis

Consideration will be given to the secondary batteries required for shadow time operation and for peak power demands. The various types of batteries will be analyzed and preliminary requirements established for the most appropriate type.

Also, the various battery charging methods will be compared and a single approach will then be conceptually designed to the block diagram level.

4.4 Data Management

The OTAES spacecraft communication and data handling requirements will be designed to the subsystem level. The results of these concepts will include: (a) diagrams showing all subsystems and their functional interconnections, (b) lists itemizing each subsystem according to function, operational mode, weight, volume, and power requirements, (c) lists showing performance goals, and (d) all pertinent substantiating data showing how these results were obtained.

An analysis of the experiment data requirements will be made to ensure that a real need for the proposed data format does exist. The data bit rate versus experiment time line operation will be analyzed and adjusted to ensure that undesirable peak bit rates do not exist.

A data management functional analysis will be performed for the purpose of defining the manned spacecraft console in consonance with crew accessories requirements.

4.5 Environmental Control Systems

A continued effort is required to analyze the ECS requirements for all OTAES conceptual spacecraft designs. Preliminary specifications will be outlined to be compatible with the results of AAP ECS studies being performed in separate studies. Trade-off areas will be treated so as to minimize or eliminate any major system differences. It is conceivable that some OTAES spacecrafts will require large volume shirt sleeve environments. State of the art of ECS will be closely monitored to ensure that recommended spacecrafts and ECS are compatible with the appropriate time frames.

An important problem introduced at this level of integration is the contamination of optical surfaces due to reaction jets, oil and particles in the cabin atmosphere, etc. The fundamental objective of this sub-task will be to estimate the possible extent of contamination and to identify control techniques to prevent such contamination. This naturally leads to a number of trade-off decisions, such as manned accessibility versus primary mirror contamination, thruster location, thruster on-off times, etc. Preferred solutions to these trade-offs will be recommended for experimental investigation where appropriate.

4.6 Crew Accessories

The crew's contribution and participation during intravehicular and extravehicular flight control and experiment activities will be treated in the conceptual designing of OTAES spacecraft systems. It is currently conceived that the flight crew will be performing OTAES mission activities under shirt sleeve, vented, and pressurized spacesuit conditions. Specification of these activities will be developed as a contractual task relating to manned operations (sub-task 3.2). The crew's activities will be programmed at maneuvering, anchoring and body restraint, work production, observation, experimentation, and egress/ingress stations.

Since the feasibility of a crew's performance at these stations is interdependent upon the OTAES spacecraft subsystem configurations and crew accessories, one of the contractual tasks will be to determine requirements for crew accessories. Crew accessories under consideration will comprise, but not be limited to, the following: restraint and containment devices, manual tools, EVA tethering and propulsion devices, lighting provisions, viewing ports, egress/ingress hatches, portable eyepieces, spacesuits and constant wear garments, and flight kit information assemblies.

4.7 Thermal Control

The recommended OTAES experiments establish tight thermal requirements upon the thermal control system. The failure to meet these requirements will seriously degrade experiment performance, if not cause a complete failure. Therefore, a critical technical area that must be analyzed as soon as meaningful data can be developed is the thermal control of the integrated experiments. To be meaningful, the analysis must include as many aspects of the entire system as is reasonable.

During Part I the spacecraft was simplified into a cylinder, and analyzed in low earth orbit and synchronous orbit, with various inclinations, and assumed various absorptivity and emissivity coefficients, skin thicknesses, and other factors. By modifying many variables it was possible to gain some understanding of the problem. Later efforts considered one typical configuration in a synchronous orbit, and were concerned with a much more complete thermal analysis of the outer skin temperatures, the active temperature control techniques on optical telescopes, the passive and active dissipation of mechanical and electrical equipment heat, cabin air conditioning, the selection of optimum mosaic-type surface coatings for proper thermal control on the outside of the vehicle, and insulation techniques.

During Part II each recommended experiment package will be analyzed in conjunction with a selected spacecraft configuration, in a selected orbit, with heat loads as generated by the sun, the earth, man, and equipment. Through active and passive techniques of thermal control will be studied, attention will be given to determining the adequacy of passive techniques. Special attention will be directed to defining the problems associated with maintaining thermal tolerances on the laser telescopes.

4.8 Systems Reliability, Specifications, and Testing

Past experience at Chrysler in large launch vehicle and spacecraft programs has revealed the necessity for investigating component specifications and reliability at the conceptual level. This material is required to support various sub-tasks. For instance a meaningful comparative reliability analysis (sub-task 3.1) requires knowledge of component reliability. If such information is not available, then this must be known. One portion of this sub-task output will be to provide this component information.

A complete list of expected experiment and spacecraft components will be made. It will indicate the required reliability, operating and test specifications, and component physical characteristics.

In addition to the component test program requirements, subsystem, and spacecraft test requirements will be outlined during this phase of the study. This information will be used to develop the test plan which is described in Task 5.0.

Figure 10 illustrates an example of a part of the output from this Task.

S/C SUBSYSTEM	COMPONENT	OPERATING TEMPERATURE	MAXIMUM TEMPERATURE RANGE	MAXIMUM ACCELERATION	PERFORMANCE SPECS.	RELIABILITY	PHYSICAL CHARACTERISTICS											ENVIRONMENTAL TEST REQUIREMENTS					
							W	C G			M OF I			L	W	H	VOL	THERMAL VACUUM	SHOCK	VIBRA-TION	MAG-NETIC	PRESS	LEAK
								X	Y	Z	X	Y	Z										
A. Electrical Power Distribution	1. Batteries																						
	2. Battery Charger																						
	3. Series Regulator																						
	4. Shunt Regulator																						
	5. Invertor																						
	6. Load Bank																						
	7. Cables																						
	8. Terminal Boards																						
	9. Busses																						
	10. Switch Selector																						
	11. Power Monitor																						
	12. Command & Control Package																						
	13. Heaters																						

Figure 10. Example of Component Specifications Summary Form

5.0 RESOURCES ANALYSIS

The purpose of resources analysis is to relate the demands of the total OTAES system to the resources available, and to ensure the most efficient use of these resources. There will be two areas of analysis: (a) analysis and preparation of detailed experiment support plans, and (b) analyses of mission cost alternatives. The individual experiment development and cost analysis is performed in sub-task 2.2. To provide total visibility of a complete operational program, supporting spacecraft plans must be developed. Sub-task 5.1 includes supporting spacecraft analysis only. The cost information from these two sub-tasks (2.2 and 5.1) is used in sub-task 5.2 Mission Cost Analysis to develop the costs of various alternatives to experiment implementation.

With reference to configured spacecraft hardware and experiment items, this analysis primarily spans the time from the hardware detail design function of NASA Phase "C" to the operational flight capability (launch of the first operational flight article) in NASA Phase "D." All costs, schedules, and manloading projections, except where specifically noted, are estimations only of this segment of the total program cycle. Facts or figures of other segments of the total program cycle may be included at times for the purpose of clarity or continuity. All estimates will be in accordance with the guidelines established in NASA PHASED PROJECT PLANNING.

5.1 Detailed Plans

Six preliminary plans will be developed during OTAES Part II. Each of these is discussed in the following sub-sections. A "most typical" spacecraft concept configuration evolved from the four concept configurations presented in the Phase I extension will be used as the estimating base. Only spacecraft hardware items will be analyzed and estimated. All OTAES program elements, i.e., financial, administrative, engineering, manufacturing, and test, will be considered in a system structure and framework of commonality.

In the development of mission system concepts, the complexities far outweigh the system commonalities and thus any attempt to extrapolate the total cost of an advanced mission system from the total cost of a previously developed system is unrealistic. At best, the estimation would be extremely gross and the associated confidence factor quite low.

To ensure a system of plans that are optimum in consistency and comprehensibility, they will be founded on a "building blocks" approach. In this approach a work breakdown structure of the total program to be analyzed is developed. The task is broken down into successively more simple elements, which then can be estimated with a high degree of confidence. The basic estimating level in this analysis will be the subsystem or major assembly. The information collected at this level will then be summarized at the next higher level, that is, the systems level. Additional information will be collected at the systems level and culminate in the summary at the totally integrated OTAES level.

5.1.1 Preliminary Design Plan

The scope of this plan shall include experiment supporting spacecraft subsystems or major assemblies to be designed, the plan and approach considered most appropriate, the time estimated for this task, and also manpower and cost estimates to accomplish the same task. The plan will further include the following as applicable: (a) development of mockup and breadboard articles in the development process, (b) planning, design and construction of required facilities, (c) production of both test qualification articles, (d) design and procurement of manufacturing tooling, (e) design and procurement of special test and checkout equipment, (f) procurement of long lead time items, (g) design, fabrication, and assembly of flight article hardware, and (h) qualification and reliability planning and testing.

5.1.2 Preliminary Manufacturing Plan

This plan has been deleted per prior NASA direction. In order to round out the other plans requiring manufacturing inputs, gross estimates only will be used.

5.1.3 Preliminary Test Plan

The scope of this plan shall include the following as applicable: (a) spacecraft integrated system as well as major subsystems testing (all experiment testing will be performed in sub-task 2.0), (b) requirements as to the number of qualification test models "boilerplate," etc., (c) test and checkout equipment requirements, (d) estimates of the complexity of the tests to be performed, (e) schedules for the performance, evaluation, and reports for the testing function, (f) costs of testing, materials, equipment, documentation, etc., and (g) manloading requirements to support the effort.

5.1.4 Preliminary Facilities Plan

The scope of this plan shall include the identification of new facilities or modification to existing facilities required for the OTAES program. Each new facility and/or modification effort will include a short narrative as to facility description, intended use, recommended site location, and time and cost estimates for the design, erection and checkout of the facility. Separate cost and schedule sheets will be prepared if several promising facility alternatives develop.

5.1.5 Preliminary Cost Plan

The scope of this plan shall include the total experiment supporting spacecraft costs for the design, manufacture, and test and systems integration functions. Total facilities costs will also be included. Data for the design and test function estimates will be gathered from each respective plan. The manufacturing cost estimate will be more approximate than those compiled for the design and test functions. Development costs will be broken down to the assemblies and systems level as applicable for sparate end item visibility.

5.1.6 Preliminary Schedule Plan

This plan will contain summarized schedules of the plans, and will present the major milestones to be accomplished.

5.2 Mission Cost Alternatives

5.2.1 Discussion

The primary purpose of a mission cost analysis is to ensure proper mission optimization through a logical cost trade-off program. To avoid arbitrary design and other engineering decisions, it is necessary that the cost trade-off analyses begin simultaneously with the identification of the mission objectivies. The cost trade-offs will be developed to a level consistent with available information. It is intended that this material be developed to the point of supporting design choices and decisions in subsequent phases of the study.

The mission cost analysis utilizes the basic cost information provided for the experiments (sub-task 2.0) and for the supporting spacecraft (sub-task 5.1) as the total base from which to trade-off mission cost alternatives. This analysis will provide a total view for comparison of the various economic mission alternatives. These are: (a) The cost of individually flown experiments; (b) The cost of experiments flown collectively on an other than OTAES vehicle; (c) The cost of experiments performed on the OTAES candidate mission approaches.

The four OTAES mission candidate approaches are: (a) Approach I: synchronous manned mission, (b) Approach II: synchronous unmanned mission, (c) Approach III: dual mission, synchronous unmanned and low earth orbit manned, (d) Approach IV: low earth orbit manned mission.

5.2.2 Analytical Elements and Derivation of Cost-Alternative Relationships

Although most of the cost of any operational program is centered within the spacecraft, in this case emphasis is given to the experiments even though they do not have an appreciable effect as far as hardware dollars but, nevertheless, do dictate the most optimum spacecraft configuration. Furthermore, the dollar amounts required to advance the technology state-of-the-art through prerequisite research and development has a tremendous impact on the total program. Spacecraft cost-estimating relationships will be analyzed in a supporting role to the experiments.

Estimating relationships having been derived, the recurring production cost, as applicable, and engineering hours for each subsystem can be applied to each spacecraft. The spacecraft recurring and nonrecurring cost elements can then be grossly tabulated. Design and development engineering and development support can be derived as a function of the summation of all subsystem engineering hours required. The remaining nonrecurring items are derived from the consideration of the spacecraft as a whole in relationship to the other elements of the mission. (See Figure 11.)

NONRECURRING COSTS (MILLIONS OF $)		
Spacecraft Initial Design and Development Engr	---	
Development Support	---	
Trainers, Simulation	---	
Test Operations	---	
Ground Support Equipment	---	
TOTAL NONRECURRING COSTS		---
RECURRING COSTS (MILLIONS OF $)		
Flight Article (Experiments + Spacecraft)		
Production Cost - Structure	---	
Production Cost - Other Subsystems	---	
Sustaining Engineering	---	
Spares (On Board)	---	
Experimentation	---	
TOTAL FLIGHT ARTICLE		---
OTHER RECURRING		
Spares	---	
Integration and Checkout	---	
Spacecraft Support	---	
Launch Vehicle	---	
Launch Operations	---	
TOTAL OTHER RECURRING		---
TOTAL RECURRING COSTS		---

Figure 11. Typical Mission Cost Element Estimates

APPENDIX A

OPTICAL TECHNOLOGY
APOLLO EXTENSION SYSTEM
PART I

EXECUTIVE
SUMMARY REPORT

OPTICAL TECHNOLOGY APOLLO EXTENSION SYSTEM PART I

EXECUTIVE SUMMARY REPORT

CONTRACT NAS 8-20256

SPACE DIVISION CHRYSLER CORPORATION

OPTICAL TECHNOLOGY
APOLLO EXTENSION SYSTEM
PART I

EXECUTIVE SUMMARY REPORT

CONTRACT NAS 8-20256

September 22, 1966

Approved by: W. W. Kloepfer
W.W. Kloepfer
Program Manager

CHRYSLER CORPORATION SPACE DIVISION, MICHOUD ASSEMBLY FACILITY
P.O. BOX 29200, NEW ORLEANS, LA. 70129

2856-9-20-66

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

EXECUTIVE SUMMARY

THE OPTICAL TECHNOLOGY APOLLO EXTENSION SYSTEM

I. INTRODUCTION

It is widely accepted that large manned orbiting telescopes and scientific data gathering instruments must be launched into space for the United States to be able to retain or establish its scientific lead in the areas of astronomy; Earth remote sensing for resources conservation to better man's existence; weather prediction for his safety and convenience; and further manned space exploration to whet his appetite for knowledge of the origin and nature of the Earth, the sun, the stars, and the universe. In addition to these optical systems, a means must be found to return this information to the Earth at high data rates from long distances in space. It is further recognized by NASA, U. S. industry, and the scientific community that the technology plateaus in these fields are not advanced enough today to assure the Government of an orderly, efficient, reliable, and successful accomplishment of these goals in the near future no matter what shortcuts are taken or "brute force" methods are used.

NASA and more specifically the Office of Advanced Research and Technology has recognized this technological gap in optical systems early enough to institute significant development plans to reach those critical technology plateaus in a timely and expeditious manner. Of these technological development programs, as numerous and varied as they are, the Optical Technology Apollo Extension System is the most significant due to its comprehensiveness in identifying the many facets of this complex undertaking.

The scientific potential of optical instruments operating in Earth-orbit above the atmosphere is generally recognized. Were it possible today to orbit and operate large telescopes to fully realize this potential, the scientific returns would be immediate and spectacular. Not only astronomy, but a whole spectrum of scientific disciplines ranging from optical communications to planetology require telescopes with such advanced characteristics. Yet, although the launch vehicle capability is essentially available, such telescopes cannot be launched today because the state of optical technology has not advanced to the point where they and their supporting subsystems can assuredly and economically be built for space application.

However, to develop optical technology to a point where the advantages of space can be fully realized will require a significant commitment of the national space program's resources. There can be no question that the potential scientific returns justify such a commitment. Because of this, and because of the commonality of requirements in several applications areas, it is extremely important that the development of the required optical technology be carefully planned in advance. Thus, an overall comprehensive development plan that is based on a detailed analysis of the technology requirements of both telescope components and their supporting subsystems, and which considers all practical means to achieve these requirements including studies, ground tests, airborne tests, and space tests, is absolutely necessary. The Optical Technology Apollo Extension System is the starting point.

II. PROGRAM PHILOSOPHY

During the course of these initial conceptual and feasibility studies, it has become increasingly clear that identification in detail of an integrated development plan for space optics technology would be extremely fruitful. In developing this plan to maintain this nation's lead in space, first consideration has been given to those technological developments which require space tests, as these, along with the necessary prerequisite ground test, will be the long lead time elements of the development program. See figure 1. Consequently, the first logical step in the development of the overall plan is to isolate those requirements which need space tests and design in an experimental test program to satisfy these requirements. The results are highly revealing.

1. Optical Technology must now be developed in a more organized and logical way.
2. A number of feasible experiments can be implemented which will provide required technological advance toward national space goals.
3. Because of its logical flow structure, it imposes an economic discipline upon itself.
4. Because it is organized and well-planned, it offers assurance of application reliability.
5. Because there are time constraints on attaining scientific knowledge, this technology must be advanced now.

Briefly, these studies were approached as follows: (a) using scientific articles and industrial reports as source materials, potential space scientific objectives which require optical technology such as astronomy, meteorology, earth remote sensing, and interplanetary missions were analyzed; (b) technology requirements for these objectives were determined; (c) alternate solutions to these problem areas were identified; (d) space experiments to achieve the above objectives were formulated; (e) supporting ground development programs were identified; (f) these experiments were integrated into a space package, and spacecraft and mission requirements to support the experiment programs were analyzed; and (g) an overall technology plan was developed which shows key development milestones in the Earth-based program, schedules for each individual experiment, and master plan alternatives for the overall experiment program to achieve the technology objectives.

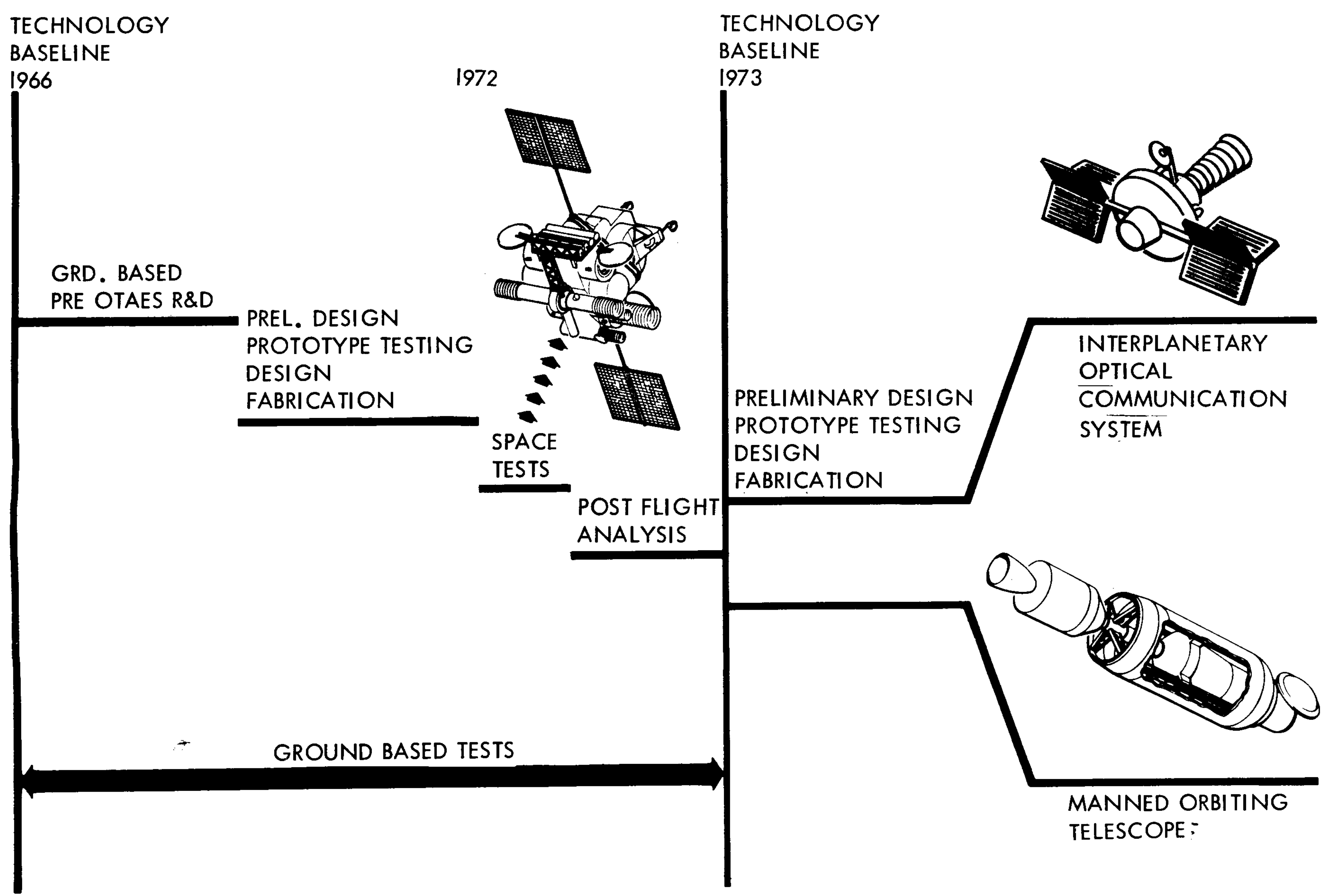


Figure 1. Space Optical Technology Development

III. CONCLUSIONS

The major conclusions of Part I of OTAES study are presented for convenience in six categories. These conclusions form the basis for the recommendations appearing in the next section.

1. Commonality

There is a broad commonality of the optical technology needed for astronomy, for remote sensing of the Earth, for meteorology, for planetary observation, and for space optical communications. That is, there is a commonality of application. See figure 2.

If the special scientific and government groups associated with each of these applications were to develop the technology required for their particular interest, the resulting programs would overlap and no one of them could be as effective in providing timely, reliable, and economic space optical technology, and NASA would find itself paying twice for its technology. Moreover, there are optical instruments which would be desirable to more than one of these special interests but whose development can be more fully justified because of the multiple applications. Consideration of the technology from the standpoint of its application, therefore, in two ways forcefully compels the conclusion that a single technology development program must be instituted and sustained.

There is also a commonality of development programs. For the optical technology which requires space testing for its development, significant advantages are gained by flying the experiments in groups even though each of them could be flown singly. For instance, the nine propagation experiments require identically the same equipment for their performance.

In summary then,

- The needed optical technology is common to all of the potential applications.
- The needed optical technology leads to common development experiments and programs.
- This commonality strongly favors a comprehensive integrated development program.

2. Completeness

The OTAES contract is limited to consideration of the technology which leads to space testing. Increased emphasis by NASA is needed to develop an orderly program for advancing the optical technology not covered by the present OTAES contract. A better statement of this conclusion is that a comprehensive, orderly program for optical technology should include in proper perspective both that part which leads to space testing and that part which does not.

		SPACE ASTRONOMY							INTERPLANTARY						METEOROLOGY						EARTH REMOTE SENSING		
TECHNOLOGY	APPLICATIONS	HIGH RESOLUTION	SPECTROSOPY	PHOTOMETRY	INTERFEROMETRY	WIDE ANGLE SURVEYS	SOLAR OBSERVATIONS	ASTRONOMETRIC	COMMUNICATIONS	MAPPING	HIGH RESOLUTION IMAGE	SURFACE CONTOUR	ATMOSPHERIC PROPERTIES	TEMPERATURE MAPPING	HIGH RESOLUTION IMAGERY	DISTRIBUTION OF CONSTITUENTS	CLOUD TOP & AEROSOL ALTITUDE	VERTICAL TEMPERATURE PROFILE	POINT-TO-POINT TURBULINCE	POINT-TO-POINT SCATTERING	HIGH RESOLUTION IMAGERY	CONTOUR MAPPING	THERMAL MAPPING
SPACE TELESCOPE TECHNOLOGY	1 MIRROR SURFACE DEGRADATION	Δ	Δ	Δ		Δ	Δ		•	•	Δ	•	•	Δ	Δ	Δ	•	Δ	•	•	Δ	•	•
	2 MIRROR FIGURE CONTROL	Δ	•	•	•	•	•	•	Δ		Δ	•	•	•	Δ	•	•	•	•	•	Δ	•	•
	3 ALIGNMENT & FOCUSING	Δ	Δ	•	Δ	•	Δ	•	Δ	•	Δ	•	•	Δ	Δ	Δ	•	Δ	•	•	Δ	•	•
	4 THERMAL COMPENSATION	Δ	Δ	•	Δ	•	•	•	Δ	•	Δ	•	•		Δ	•	•		•		Δ	•	•
	5 BEAM STABILITY	Δ	Δ	•	Δ	•	•	•	•		Δ		•		Δ						Δ	•	•
	6 PRECISION DEPLOYMENT	Δ			Δ		Δ				Δ				Δ						Δ		
	7 BAFFLES	•	•	•	•	•	Δ	•	•	•	•				Δ						Δ		
	8 LAUNCH ISOLATION	Δ	Δ	•	Δ	•	Δ	•	Δ		Δ			•	Δ	Δ	•	•	•	•	Δ		
	9 SMALL DISPLACEMENT ACTUATORS	Δ	Δ	Δ	Δ	•	Δ	Δ	Δ		Δ				Δ						Δ		
CONTROL & STABILIZATION	10 FINE ERROR SENSORS	Δ	Δ	Δ	•		•		Δ		Δ		Δ		Δ						Δ	Δ	Δ
	11 FINE BEAM DEFLECTORS	Δ	Δ	Δ	•		•		Δ		Δ				Δ						Δ		
	12 ISOLATION TECHNIQUES	Δ	Δ	•	•	•	Δ	Δ			Δ				Δ						Δ		
	13 ACQUISION	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ		Δ		•	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	•
	14 IMAGE MOTION COMPENSATION									Δ	Δ	Δ		•	Δ	Δ	Δ	Δ			Δ		
DETECTORS	15 HIGH RESOLUTION IMAGE TUBES	Δ	Δ		•		Δ			•	Δ				Δ						Δ		
	16 LOW LEVEL IMAGE TUBES	Δ	Δ	Δ		Δ				Δ	Δ												
	17 BROADBAND PHOTOELECTRIC DET.			Δ										•									•
	18 LARGE AREA PHOTO CATHODES	Δ									Δ				Δ						Δ		
	19 FAR INFRARED DETECTORS		Δ	Δ		Δ	Δ						Δ		Δ	Δ		Δ			Δ	Δ	Δ
	20 DRY EMULSIONS	Δ	Δ	Δ	Δ	Δ	Δ	Δ			Δ				Δ	•	•				Δ	Δ	
	21 HIGH DATA CAPACITY PHOTOGRAPHIC RECORDING	Δ	•			Δ	•			Δ	Δ												
	22 XUV SENSITIVE PHOTO EMULSIONS	Δ	Δ			Δ	•				Δ		•			•					Δ	Δ	•
	23 MECHANICAL IMAGE SCANNING												Δ		Δ						Δ	Δ	Δ
LASERS	24 DIRECT DETECTION								Δ		Δ	Δ		Δ			Δ		Δ	Δ		Δ	
	25 HETERODYNE DETECTION								Δ		Δ			Δ			Δ		Δ	Δ			
	26 ATMOSPHERIC TRANSFER FUNCTION								Δ		Δ	Δ		Δ		•	•	•	Δ	Δ		Δ	
	27 SCATTERING & ABSORPTION											Δ		Δ			Δ		Δ	Δ		Δ	
	28 RANGE RATES											Δ										Δ	
AUXILIARY DEVICES	29 DISSECTOR		Δ																				
	30 OBJECTIVE GRATING MOSAIC					Δ																	
	31 MICHELSON INTERFEROMETER				Δ			•															
	32 FABRY PEROT INTERFEROMETER				Δ			•															
	33 PHOSPHOR CAMERA					Δ																	
	34 UV CORONOGRAPHY						Δ																
	35 SLIT SPECTROGRAPH		Δ				Δ																

▢ WEAK RELATIONSHIP ▢• SIGNIFICANT RELATIONSHIP ▢Δ MAJOR REQUIREMENT

Figure 2. Commonality of Technology Matrix

The ultimate responsibility for this planning, of course, rests with NASA but the needed program should so intertwine with the OTAES program as to necessitate the participation by the OTAES contractor in the technology planning.

A fuller treatment of technology now excluded from OTAES study by contractor specialists should be defined so as to take advantage of the potential experiments which do not qualify for space testing but are nevertheless important elements of a comprehensive program.

3. Experiment Program

The OTAES has identified 15 experiments which are recommended for flight. Illustrative experiment concepts have been synthesized for the purpose of establishing individual experiment feasibility, compatibility within logical groupings of related experiments, and practicality within the context of supporting technologies. In essence, these studies have bounded the problem. The results show that an OTAES would make a significant and needed contribution to the national space program, that OTAES is technologically and economically feasible, and that the OTAES mission concept imposes no extraordinary support requirements. These conceptual studies have identified critical development areas and test programs which must precede the construction and launch of an orbiting optical technology experiment system. However, it cannot be said that these experiments and the OTAES alternative missions are truly designed. The effort has only been carried to a point sufficient to assure the feasibility and practicality of an OTAES development program and to be certain that such a program would be a significant contribution to the national space goals.

The recommended experiments are:

1. Optical Heterodyne Detection on Earth.
2. Optical Heterodyne Detection on the Spacecraft.
3. Direct Detection Space-to-Ground.
4. Communication with 10 Megahertz Bandwidth.
5. Precision Tracking of a Ground Beacon.
6. Point Ahead and Space-to-Ground-to-Space Loop Closure.
7. Transfer Tracking from One Ground Station to Another.
8. Phase Correlation Measurements.
9. Pulse Distortion Measurements.
10. Primary Mirror Figure Test and Correction.
11. Thin Mirror Nesting Principle and Erection and Alignment of Large Optics in Space.
12. Fine Guidance.
13. Comparison of Isolation Techniques.

14. Interferometer Systems.

15. Segmented Optics.

4. Missions

Nine different missions involving four different launch vehicles were evaluated from the standpoint of performing the recommended OTAES experiments. Four of these were selected as candidate missions. Furthermore, it was concluded that all of the experiments recommended in this study could be performed on a synchronous manned mission. Alternatively, all experiments except one, Interferometer Development, could be performed on a combination low earth orbit manned mission and a synchronous unmanned mission. Within certain constraints a synchronous orbit coupled with the judicious choice of ground station configuration permits all of the experiments to be performed on a single ground station complex including terminals for point ahead and tracking transfer experiments.

A preliminary time line analysis indicated that the manned portion of a synchronous mission could be accomplished in 15.5 days. During this period all recommended experiments could be performed at least once.

In summary,

- There are several alternatives for performing the recommended experiments, and
- None of the alternatives require major spacecraft or space vehicle development, and
- One ground station complex link is sufficient.

5. Spaceborne Support

An evaluation of the required spacecraft support indicated that all experiments could be performed with modified Apollo hardware characteristic of AAP missions. Although more than 20 configurations were considered, it was concluded that the performance of OTAES experiments would not require a major spacecraft development program. Apollo modifications planned for other missions would satisfy most OTAES requirements.

Similarly, spacecraft subsystem requirements could be satisfied with either existing or planned technology. For instance, for a mission in which all experiments are performed on one flight, the preferred power system would use oriented solar panels to augment the existing Apollo systems. Furthermore, the spacecraft attitide stability should be provided by control moment gyros with reaction jets used for periodic dumping of accumulated angular momentum. Although the control moment gyros would represent a modification to Apollo spacecraft, this specific technology is advancing rapidly independent of the OTAES program and, in fact, might well be adapted to the LEM Ascent Stage for such programs as the Apollo Telescope Mount.

In summary,

- All flight experiments can be performed with modified Apollo hardware without a major spacecraft development program, and
- Subsystem technologies are adequate to support the experiments.

6. OTAES Schedules

Given a pre-OTAES research and development program as identified in the OTAES study, the maximum required time to the first OTAES launch capability is approximately seven years. The pre-OTAES research and evelopment program would require a maximum of three years prior to OTAES preliminary design. There is very small variation in experiment availability, which reflects into a small schedule variation for each of the missions. Figures 3 and 4 give the experiment availability for 16 recommended experiments. Figure 5 shows the flight data for the four recommended missions. The pacing item in experiment availability is the telescope development design and fabrication.

In summary,

- The schedules for flight experiments call for lead times that are long enough to impart some urgency to getting started now.

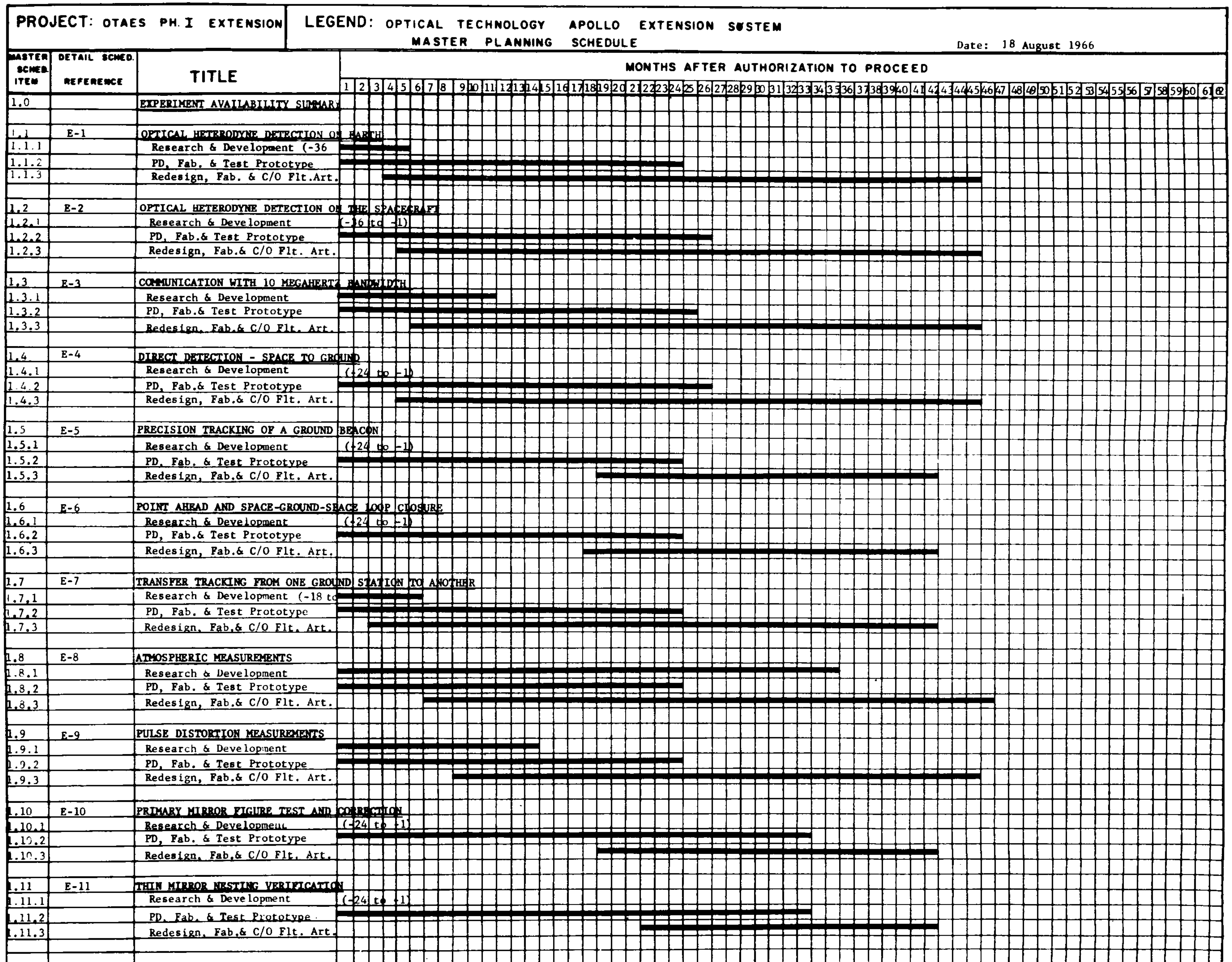

PROJECT: OTAES PH. I EXTENSION
LEGEND: OPTICAL TECHNOLOGY APOLLO EXTENSION SYSTEM
MASTER PLANNING SCHEDULE
Date: 18 August 1966
MASTER SCHED. ITEM
DETAIL SCHED. REFERENCE
TITLE
MONTHS AFTER AUTHORIZATION TO PROCEED
1.0 EXPERIMENT AVAILABILITY SUMMARY
1.1 E-1 OPTICAL HETERODYNE DETECTION ON EARTH
1.1.1 Research & Development (-36
1.1.2 PD, Fab. & Test Prototype
1.1.3 Redesign, Fab. & C/O Flt.Art.
1.2 E-2 OPTICAL HETERODYNE DETECTION ON THE SPACECRAFT
1.2.1 Research & Development (-36 to -1)
1.2.2 PD, Fab.& Test Prototype
1.2.3 Redesign, Fab.& C/O Flt. Art.
1.3 E-3 COMMUNICATION WITH 10 MEGAHERTZ BANDWIDTH
1.3.1 Research & Development
1.3.2 PD, Fab.& Test Prototype
1.3.3 Redesign, Fab.& C/O Flt. Art.
1.4 E-4 DIRECT DETECTION - SPACE TO GROUND
1.4.1 Research & Development (-24 to -1)
1.4.2 PD, Fab.& Test Prototype
1.4.3 Redesign, Fab.& C/O Flt. Art.
1.5 E-5 PRECISION TRACKING OF A GROUND BEACON
1.5.1 Research & Development (-24 to -1)
1.5.2 PD, Fab. & Test Prototype
1.5.3 Redesign, Fab.& C/O Flt. Art.
1.6 E-6 POINT AHEAD AND SPACE-GROUND-SPACE LOOP CLOSURE
1.6.1 Research & Development (-24 to -1)
1.6.2 PD, Fab.& Test Prototype
1.6.3 Redesign, Fab.& C/O Flt. Art.
1.7 E-7 TRANSFER TRACKING FROM ONE GROUND STATION TO ANOTHER
1.7.1 Research & Development (-18 to
1.7.2 PD, Fab. & Test Prototype
1.7.3 Redesign, Fab.& C/O Flt. Art.
1.8 E-8 ATMOSPHERIC MEASUREMENTS
1.8.1 Research & Development
1.8.2 PD, Fab. & Test Prototype
1.8.3 Redesign, Fab.& C/O Flt. Art.
1.9 E-9 PULSE DISTORTION MEASUREMENTS
1.9.1 Research & Development
1.9.2 PD, Fab. & Test Prototype
1.9.3 Redesign, Fab.& C/O Flt. Art.
1.10 E-10 PRIMARY MIRROR FIGURE TEST AND CORRECTION
1.10.1 Research & Development (-24 to -1)
1.10.2 PD, Fab. & Test Prototype
1.10.3 Redesign, Fab.& C/O Flt. Art.
1.11 E-11 THIN MIRROR NESTING VERIFICATION
1.11.1 Research & Development (-24 to -1)
1.11.2 PD, Fab. & Test Prototype
1.11.3 Redesign, Fab.& C/O Flt. Art.

Figure 3

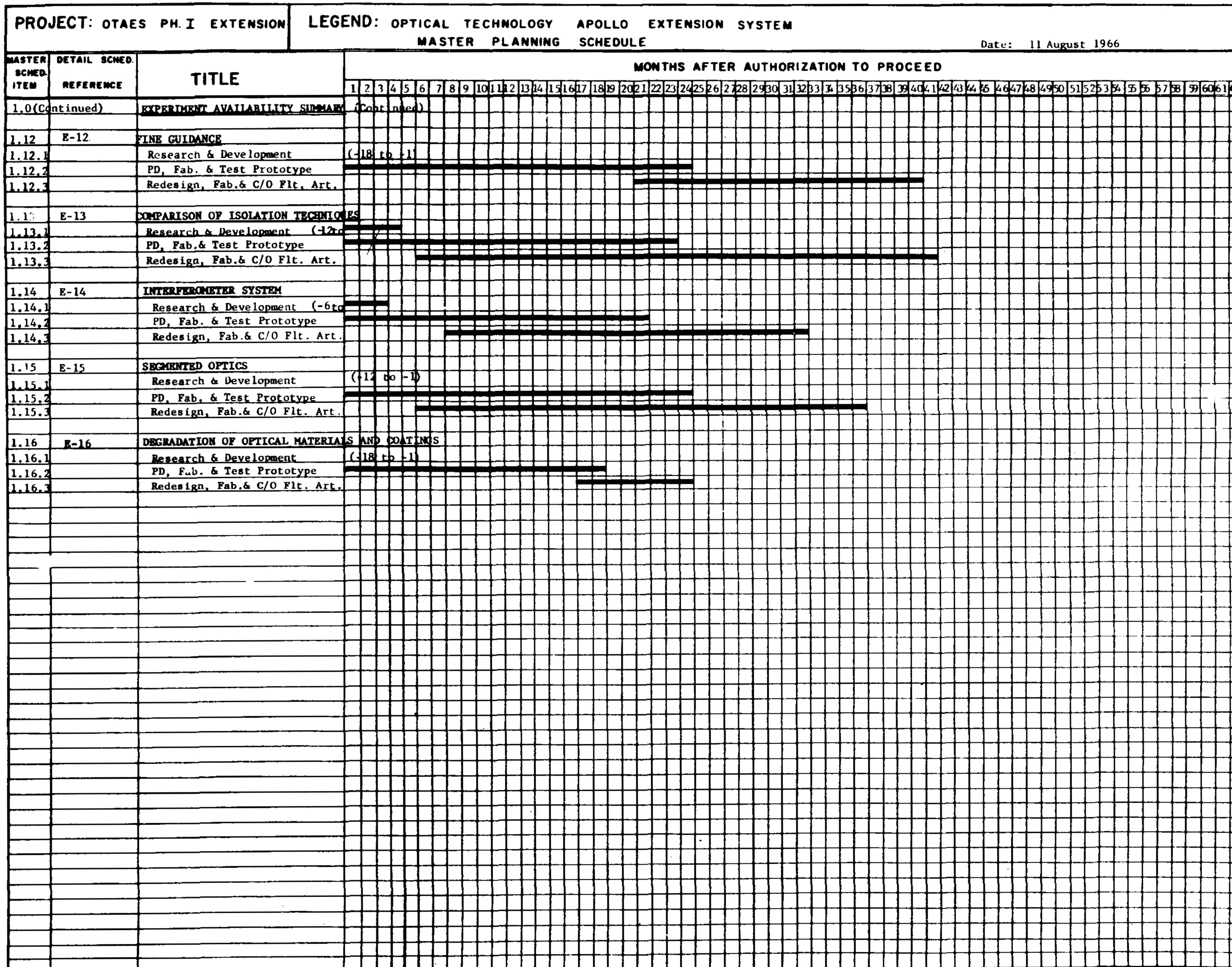

PROJECT: OTAES PH. I EXTENSION
LEGEND: OPTICAL TECHNOLOGY APOLLO EXTENSION SYSTEM
MASTER PLANNING SCHEDULE
Date: 11 August 1966
MASTER SCHED. ITEM
DETAIL SCHED. REFERENCE
TITLE
MONTHS AFTER AUTHORIZATION TO PROCEED
1.0(Continued)
EXPERIMENT AVAILABILITY SUMMARY (Continued)
1.12 E-12 FINE GUIDANCE
1.12.1 Research & Development (-18 to -1)
1.12.2 PD, Fab. & Test Prototype
1.12.3 Redesign, Fab.& C/O Flt. Art.
1.13 E-13 COMPARISON OF ISOLATION TECHNIQUES
1.13.1 Research & Development (-12to
1.13.2 PD, Fab.& Test Prototype
1.13.3 Redesign, Fab.& C/O Flt. Art.
1.14 E-14 INTERFEROMETER SYSTEM
1.14.1 Research & Development (-6to
1.14.2 PD, Fab. & Test Prototype
1.14.3 Redesign, Fab.& C/O Flt. Art.
1.15 E-15 SEGMENTED OPTICS
1.15.1 Research & Development (-12 to -1)
1.15.2 PD, Fab. & Test Prototype
1.15.3 Redesign, Fab.& C/O Flt. Art.
1.16 E-16 DEGRADATION OF OPTICAL MATERIALS AND COATINGS
1.16.1 Research & Development (-18 to -1)
1.16.2 PD, Fab. & Test Prototype
1.16.3 Redesign, Fab.& C/O Flt. Art.

Figure 4

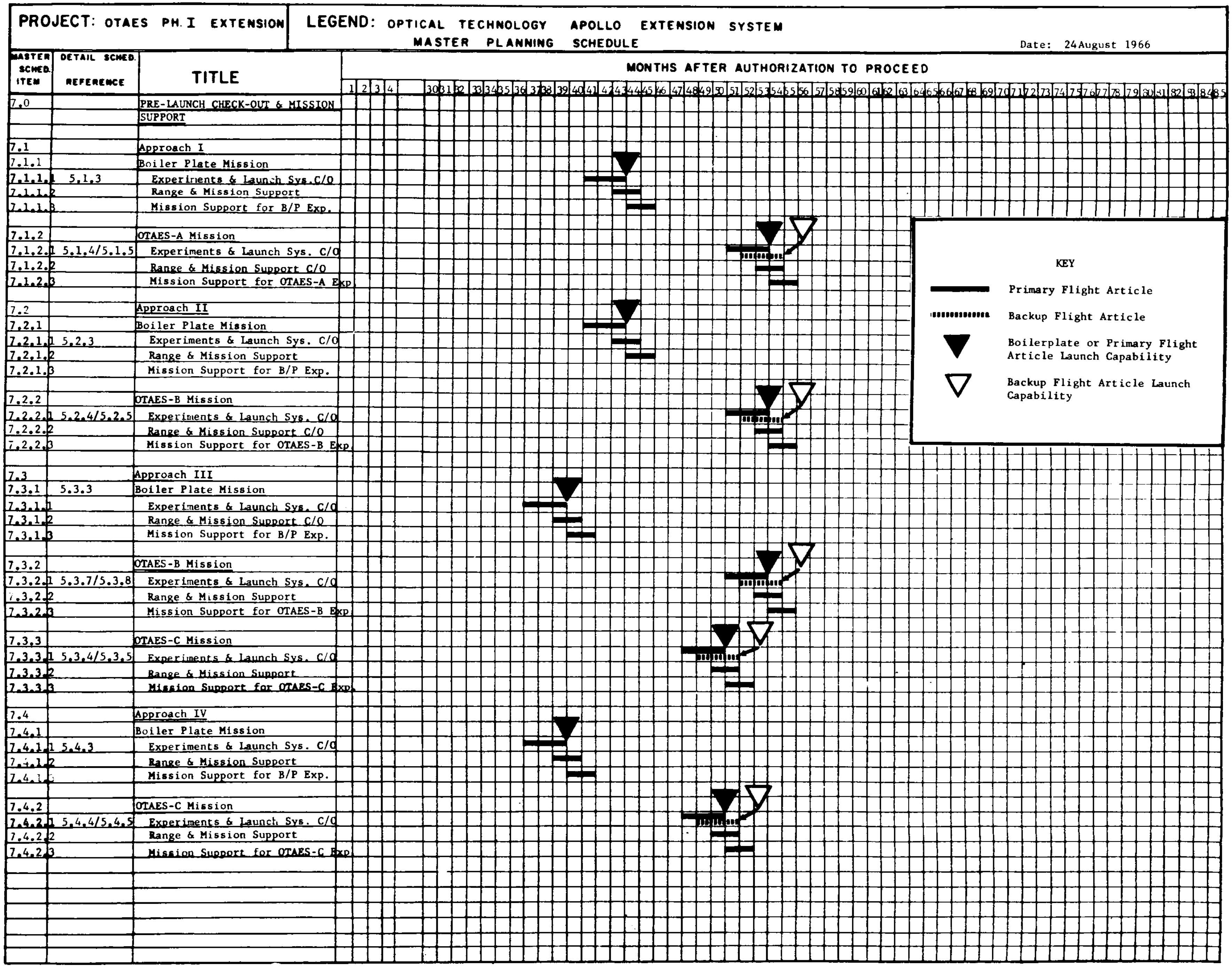

PROJECT: OTAES PH. I EXTENSION
LEGEND: OPTICAL TECHNOLOGY APOLLO EXTENSION SYSTEM
MASTER PLANNING SCHEDULE
Date: 24August 1966
MASTER SCHED. ITEM
DETAIL SCHED. REFERENCE
TITLE
MONTHS AFTER AUTHORIZATION TO PROCEED
7.0 PRE-LAUNCH CHECK-OUT & MISSION SUPPORT
7.1 Approach I
7.1.1 Boiler Plate Mission
7.1.1.1 5.1.3 Experiments & Launch Sys.C/O
7.1.1.2 Range & Mission Support
7.1.1.3 Mission Support for B/P Exp.
7.1.2 OTAES-A Mission
7.1.2.1 5.1.4/5.1.5 Experiments & Launch Sys. C/O
7.1.2.2 Range & Mission Support C/O
7.1.2.3 Mission Support for OTAES-A Exp
7.2 Approach II
7.2.1 Boiler Plate Mission
7.2.1.1 5.2.3 Experiments & Launch Sys. C/O
7.2.1.2 Range & Mission Support
7.2.1.3 Mission Support for B/P Exp.
7.2.2 OTAES-B Mission
7.2.2.1 5.2.4/5.2.5 Experiments & Launch Sys. C/O
7.2.2.2 Range & Mission Support C/O
7.2.2.3 Mission Support for OTAES-B Exp
7.3 Approach III
7.3.1 5.3.3 Boiler Plate Mission
7.3.1.1 Experiments & Launch Sys. C/O
7.3.1.2 Range & Mission Support C/O
7.3.1.3 Mission Support for B/P Exp.
7.3.2 OTAES-B Mission
7.3.2.1 5.3.7/5.3.8 Experiments & Launch Sys. C/O
7.3.2.2 Range & Mission Support
7.3.2.3 Mission Support for OTAES-B Exp
7.3.3 OTAES-C Mission
7.3.3.1 5.3.4/5.3.5 Experiments & Launch Sys. C/O
7.3.3.2 Range & Mission Support
7.3.3.3 Mission Support for OTAES-C Exp.
7.4 Approach IV
7.4.1 Boiler Plate Mission
7.4.1.1 5.4.3 Experiments & Launch Sys. C/O
7.4.1.2 Range & Mission Support
7.4.1.3 Mission Support for B/P Exp.
7.4.2 OTAES-C Mission
7.4.2.1 5.4.4/5.4.5 Experiments & Launch Sys. C/O
7.4.2.2 Range & Mission Support
7.4.2.3 Mission Support for OTAES-C Exp
KEY
Primary Flight Article
Backup Flight Article
Boilerplate or Primary Flight Article Launch Capability
Backup Flight Article Launch Capability

Figure 5

IV. RECOMMENDATIONS

As a result of the OTAES Phase I study, a number of recommendations have been prepared. These recommendations are presented by categories.

General Optical Technology

1. Defintion of the projected optical technology needs in each of the application areas of astronomy, Earth remote sensing, meteorology, and optical communications. should be continued.

2. A study should be initiated to identify those technologies not in specific support of flight experiments. This will complement the optical technology associated with the OTAES experiments.

3. An overall optical technology program plan should be developed to relate these two programs and others which will have impact.

OTAES Flight Program

A. Experiments

4. It is recommended that 15 space experiments be flown. These are:

   a. Optical Heterodyne Detection on Earth.

   b. Optical Heterodyne Detection on the Spacecraft.

   c. Direct Detection Space-to-Ground.

   d. Communication with 10 Megahertz Bandwidth.

   e. Precision Tracking of a Ground Beacon.

   f. Transfer Tracking from One Ground Station to Another.

   g. Point Ahead and Space-to-Ground-to-Space Loop Closure.

   h. Phase Correlation Measurements.

   i. Pulse Distortion Measurements.

   j. Primary Mirror Figure Test and Correction.

   k. Thin Mirror Nesting Principle and Erection and Alignment of Large Optics in Space.

   l. Fine Guidance.

   m. Comparison of Isolation Techniques.

   n. Interferometer System.

   o. Segemented Optics.

5. A continued effort in defining new OTAES experiments should be maintained.

6. In particular, detector technology requires further investigation as an area in which fruitful space experiments might evolve.

7. The development of experiment justification should be continued and further supported by the new analyses recommended as necessary in the continuation of OTAES work.

B. Spacecraft & Missions

8. Four candidate spacecraft are recommended for further study to identify the configuration which most nearly meets all of the requirements. These are:

   a. Modified Apollo Synchronous Spacecraft.

   b. Synchronous Spacecraft.

   c. Dual Mission Spacecraft.

   d. Near Earth Orbit LEM Spacecraft.

9. A detailed study of the use of the Apollo spacecraft on a manned synchronous mission should be undertaken.

10. The feasibility of implementing some of the recommended experiments should be explored in greater detail. For instance, a control and stabilization simulation, a dynamic analysis, and a thermal analysis should be performed on the integrated configurations developed in this part of the OTAES study.

11. Four candidate missions are recommended for the OTAES program. These are:

   a. Manned synchronous misssion.

   b. Unmanned synchronous mission.

   c. Manned low earth orbit mission.

   d. Single-launch, dual mission combining the un-manned synchronous and manned low earth orbit missions.

12. These mission and spacecraft candidates should be investigated for the purpose of determining an optimum OTAES flight program.

C. Operation Analysis

13. Further definition of OTAES support requirements such as the ground station, data handling, etc. is needed.

14. Further definition of the man/experiment interface is necessary to coincide with the level of experiment conceptual detail and the integrated experiment groupings developed in Part I.

15. Although the experiment concepts described in the report are feasible, they are not necessarily optimum. In particular, a consideration of alternatives which would enhance the overall OTAES probability of success (insure maximum technological data) is needed. A series of conditional probability analyses are needed which, when assembled, will relate success in all flight phases (launch, injection, experiment, etc.) with mission, spacecraft, and experiment grouping alternatives.

16. Specific elements of the above generated reliability estimates should be compared to reliability estimates for accomplishing the technological experiment objective directly in the application without the intermediate step. Such a comparison would yield a quantification of the OTAES technological gain.

17. It is recommended that the high reliability standards of the manned space program be maintained in all the space areas through the development of optimum technology to insure maximum national support of these future potential space goals.

18. Further analysis of the space operational environment for individual experiments is required. In particular, the contaminant environment and the influence of contaminant particle size and distribution on mirror degradation characteristics should be determined.

D. Planning

19. An OTAES technical plan should be developed which will describe the tasks required in the following OTAES phase and a plan for accomplishing these tasks.

20. An OTAES preliminary facility plan should be developed which defines the nature and extent of the facilities required for the OTAES flight program.

21. An OTAES preliminary test plan should be developed which indicates the nature and extent of test and checkout activity for the OTAES flight program.

22. An OTAES preliminary schedule should be prepared which will establish a feasible timing for development of the OTAES flight program and will identify the critical paths in this development and the urgency of timing of the specific development tasks.

23. An OTAES preliminary cost plan should be developed which will indicate the cost of the OTAES alternatives.

V. RECOMMENDED OTAES EXPERIMENTS

The experiments developed in the course of these studies have been categorized into three groupings for the purpose of generalized description.

Optical Propagation Group

The atmosphere has been studied for centuries from Earth-bound observatories using the noncoherent light from stars. Rockets and satellites now permit remote measurements of the Earth and its atmosphere. Over the past decade, the national space program has accumulated many such data; and a large portion of these data were measured in the ultraviolet, visible, and infrared. To make optimum use of remotely sensed data, more must be known about the physics of the atmosphere and the effect of the atmosphere on optical signals passing through it. As a tool to advance our knowledge in these areas the laser possesses two highly useful properties: spatial coherence and temporal coherence. A laser transmitter can emit an extremely narrow, intense beam of monochromatic light. Furthermore, since they operate at frequencies sensitive to atmospheric absorption and scattering and variations in the index of refraction, the laser is the most promising instrument for obtaining a better understanding of the turbulent structure of the atmosphere. To study the physics of the atmosphere using a spaceborne light source is to study the character of a space-ground transmission path. The establishment of such a path is tantamount to establishing an optical communication link. Indeed, the most promising operational application for lasers is wideband communication over extremely long distances. But, to achieve this goal, a foundation of spaceborne optical communication engineering data must be obtained. The propagation experiments, singly and as a group, are advanced as a means for studying the Earth's atmosphere as a prerequisite to the development of alternatives in the field of communication. The optical propagation group is comprised of nine experiments. This group is pictorially represented in figure 6. The conceptual detail of the spaceborne telescopes are shown in figure 7 and 8. Four of the experiments are directly associated with optical communications. Collectively, the space-to-ground communication experiments provide a comparison of the fundamental communication techniques: direct detection and heterodyne detection. Also, the heterodyne experiment, which is performed both in space and on the ground, is formulated on a scale sufficient to allow comparison between laser and radio frequency communication. Direct detection, which has the advantages of system simplicity, lenient pointing tolerances, and an advanced state of ground based development, is also the subject of a proposed experiment. Intimately related to the detection experiments, but operationally distinct, is the 10 megahertz bandwidth communication experiment in which the objective is to actually compare the wideband optical communication alternatives.

Three experiments of the optical propagation group are concerned with the development of the technology required for eventual optical communication from deep space. In order to utilize the narrow beams in which the laser power may be concentrated requires a pointing capability commensurate with the beam divergence (e.g., 0.1 arc-second). Achieving this accuracy requires a precise reference from the ground station to the spacecraft. This reference is established by precise tracking of an upcoming laser beam. Such tracking is the subject of one experiment. It should be pointed out

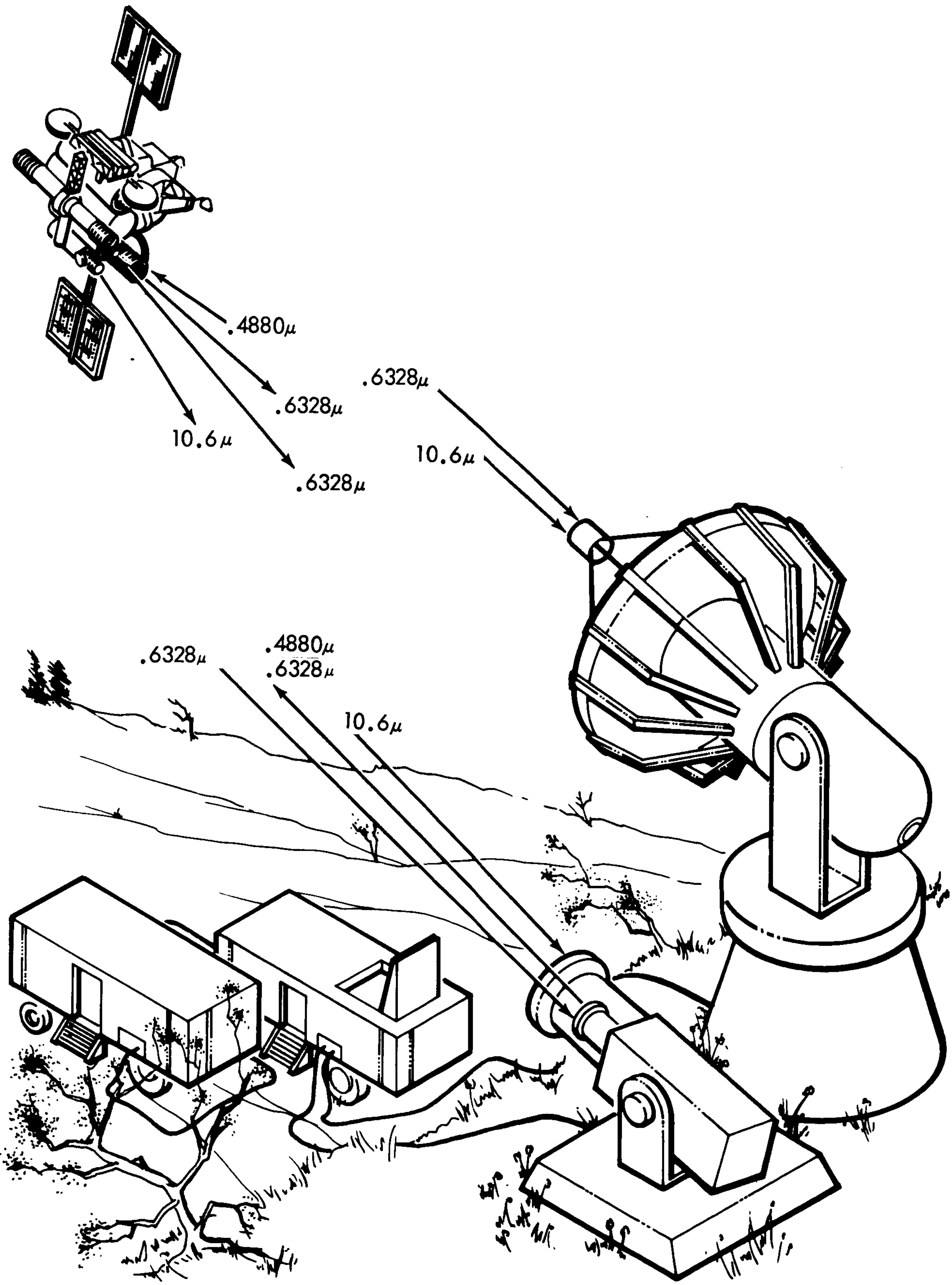


Figure 6. Spaceborne and Ground Equipment Concept for the Optical Propagation Experiment

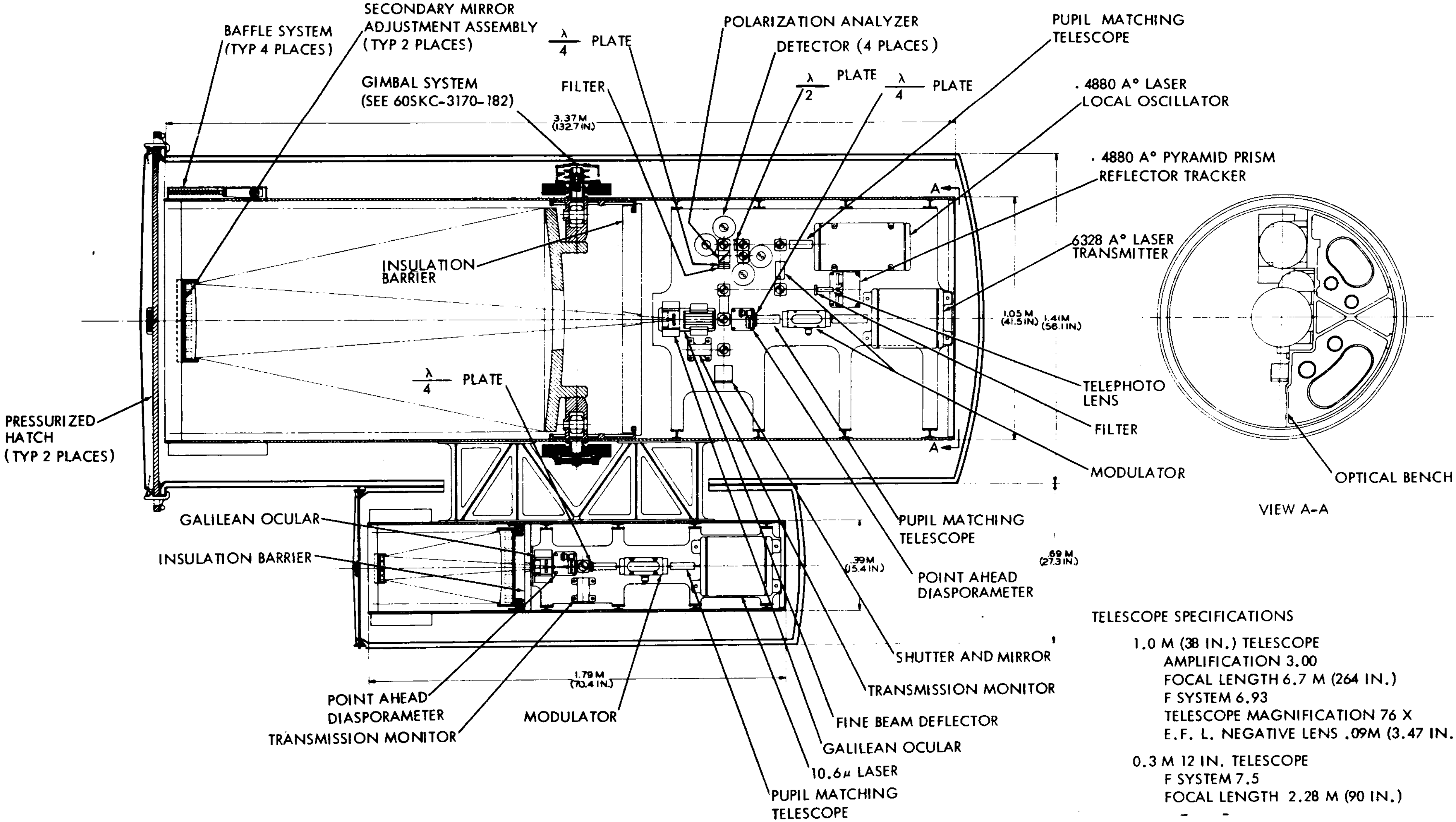


Figure 7. One Meter Telescope with Three-tenths Strapped Down Telescope

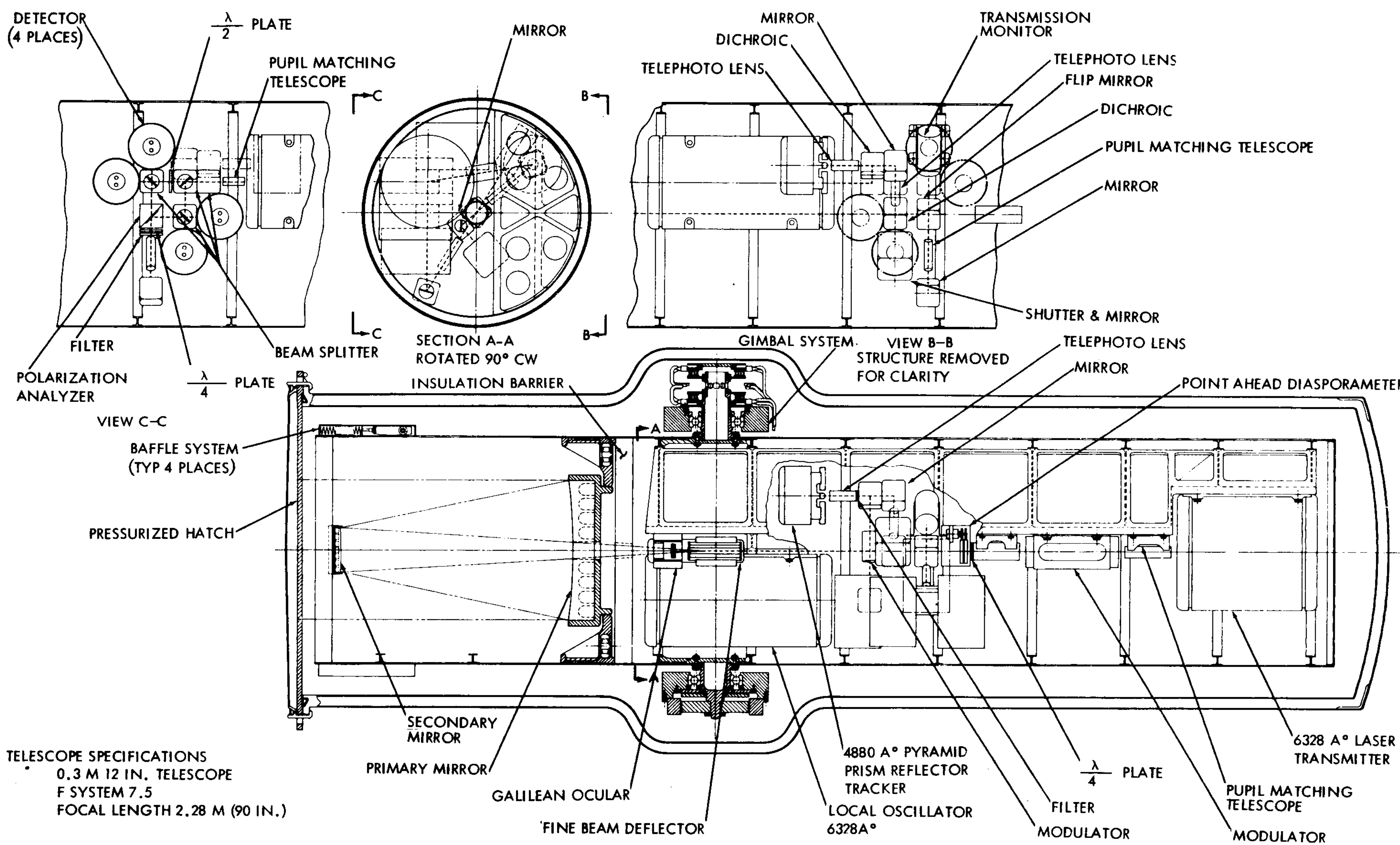


Figure 8. Three-tenths Meter Gimballed Telescope

that this tracking is required to support the other experiments, so that no additional spacecraft equipment is required.

An important element of the communications experiements is to simulate, as nearly as is practical, communication conditions from deep space. For tests whose alternate objective is the development of operational techniques, it is important that the technology be exercised under realistic conditions since communication from the planets will require, among other things, the transfer of tracking from one ground station to another. The objective of one of the proposed experiements is to develop this capability. Another particularly difficult problem with a two-way communication link with deep space is the lead angle which must be incorporated into the transmitter beam. Caused by the relative velocities between the spacecraft and the ground station and the relatively long transit times, the lead angle requirement may typically be as great as 40 arc-seconds for a Mars flyby.

Two experiments of the optical propagation group are designed to explore important properties of the atmosphere in order to first test a technique for measuring phase variations as a function of time, with a highly monochromatic laser source and, second, to study phase and amplitude characteristics of the atmosphere as a transmission medium.

Telescope Technology Group

The second major group of proposed experiments is designed to advance space telescope technology. Figure 9 is a detailed experiment well concept which facilitates this group. The outstanding goal in space astronomy, recommended by the Space Science Board, is the 3-meter (120-inch) telescope. The telescope aperture, by virtue of its size, establishes its light gathering capability. The light gathering power of this telescope is such that if complemented with a very high resolution capability, i.e., to its diffraction limit, it will permit astronomical observations not heretofore possible.

However, telescope resolution, exclusive of the particular optical configuration, is affected by mirror and/or lens surface shape deviation and smoothness, optical system alignment, optical materials and coatings, and lens material homogeneity. The most formidable problem is that of maintaining primary mirror diffraction-limited quality. To do this requires sensible and precise techniques for determining the deviation of the mirror figure from its required shape and, if a deviation exists, suitable methods for correcting the mirror figure so that the undesired deviations are removed.

Further, a mirror may return to its figure over most of its surface but fail to completely return on the balance. An evaluation of this condition under a space condition would be the only way to ascertain that the ground test conditions were not the cause of the discrepancy from prediction. In addition, a study was made of various methods for simulation of a zero g environment on earth. Each approach reviewed had serious drawbacks resulting in a need for space testing.

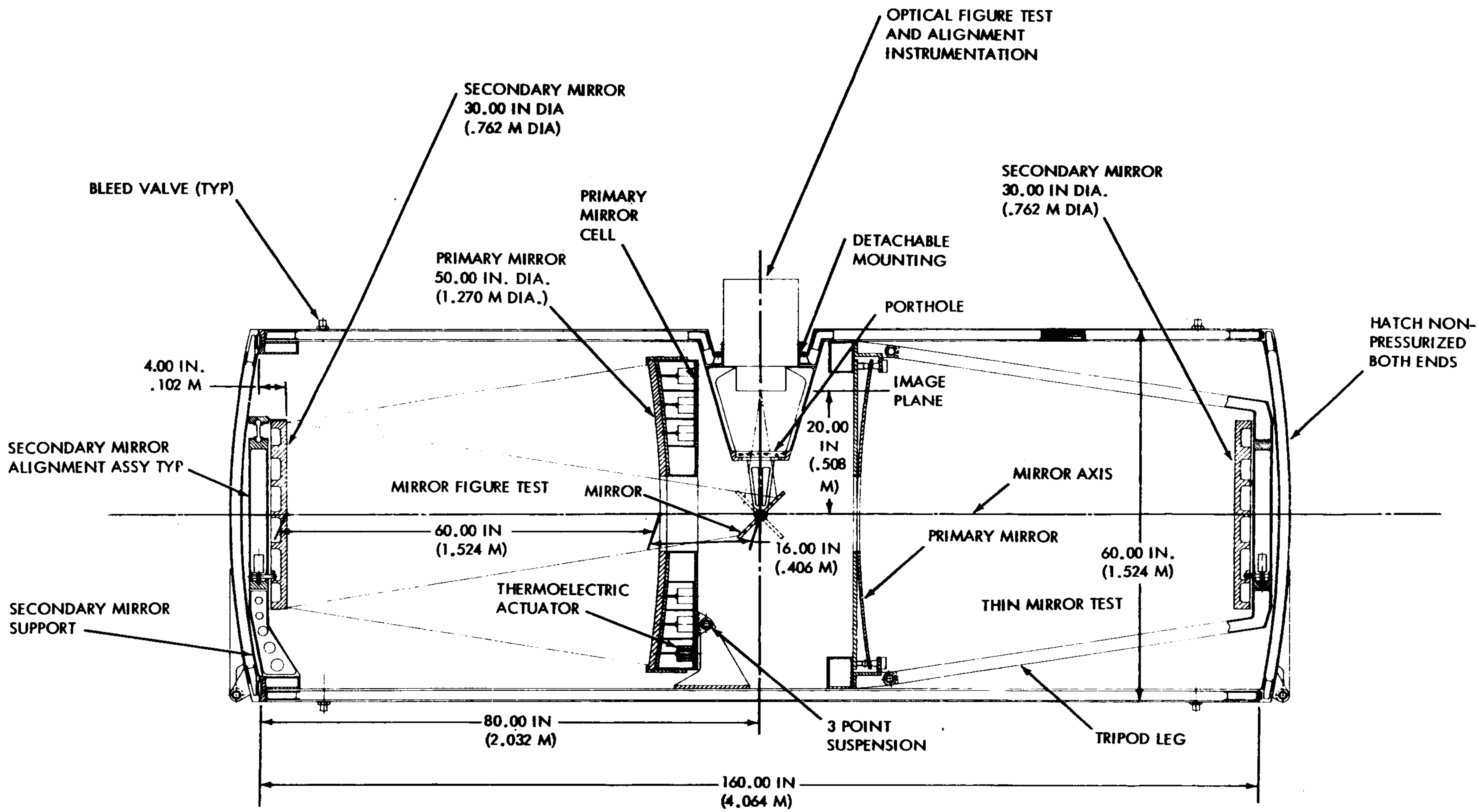


Figure 9. Primary Mirror Experiment Well

One possible solution to these problems is the use of a segmented primary mirror in the telescope. It is proposed as part of OTES to design, orbit, and test a small segmented telescope. The segmented telescope performance will be tested both by astronomical photography and by figure testing. A comparison of these results to ground-based results and predictions on the same telescopes will then allow a determination of the environmental affects on segmented mirror performance and, thus, of the merits of the concept. Another experiment proposes techniques for aleviating the figure control problem. By uniformly supporting a thin mirror during manufacture to eliminate the gravity-induced distortion, the mirror will tend to return to its proper figure in a low-g space environment. Figure 10 illustrates a possible future space operation including such a thin mirror concept.

Stellar Oriented Experiment Group

Experiments of this last major group are grouped together because, from an operation viewpoint, they share common subsystems. Figure 11 is a detailed telescope concept which facilitates this group.

The fine guidance experiment will serve the purpose of space development and testing of a highly stable star pointing system applicable to large telescopes (at least 100 inches). For this experiement the comparable performance is a pointing system stable to one one-hundredth of one second of arc when guiding on dim stars (+ 10 mag A0 star) against different background brightnesses.

The requisite testing and data gathering (of the proposed experiment) essential to the design of a large telescope fine guidance system include: evaluating the pointing stability as a function of star color temperature and magnitude; evaluating two types (at least) of fine sensors; testing reacquisition and fine guidance on consecutive half orbits (which is important in near Earth orbit missions) , and evaluating different fine beam deflectors.

The objective of the second experiment in this group is the development of isolation techniques. Precise stabilization of a space telescope, as discussed above, requires isolation from man-produced distrubances originating in the spacecraft. Several techniques, all of which are designed specifically to take advantage of zero g space conditions, are proposed for experimentation. One of these techniques, that of spring suspension, is depicted in figure 12.

The last experiment in the stellar oriented group is the stellar interferometer experiment. A stellar interferometer stationed in Earth orbit, where beam vibration and atmospheric turbulence can be minimized, will be a valuable tool for increasing our knowledge of stellar and galactic dimensions, Cepheid characteristics, and mechanics of stellar systems.

The full effects of the space environment on the instrument cannot be obtained on Earth nor can they be adequately simulated in the presence of gravity. Data are also needed on the combination and transmission of the many disturbances as inputs to a beam analysis model. In short, comparison of beam concepts must be accomplished in space.

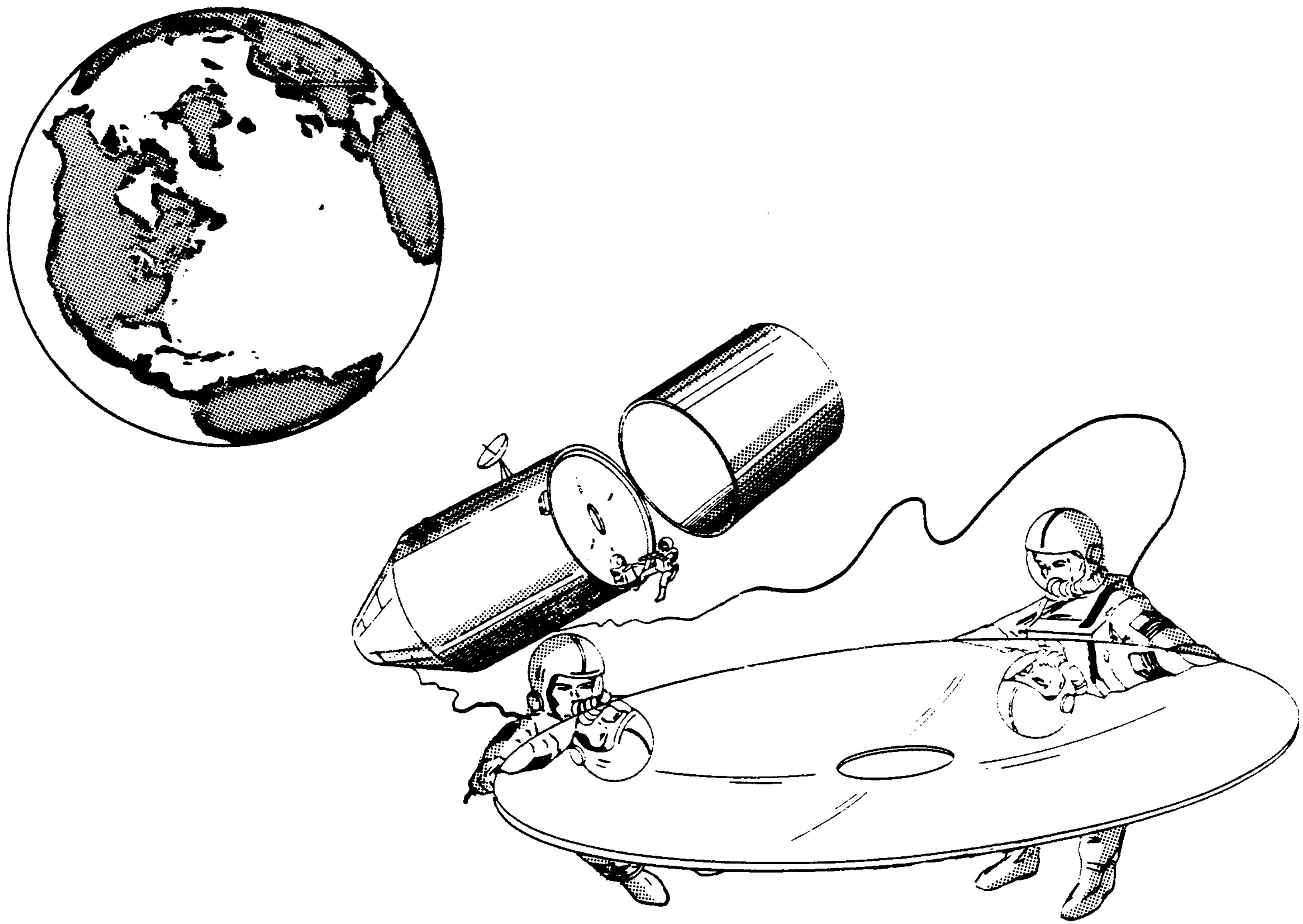


Figure 10. "Thin Mirror" Replacement in Space-borne Telescope

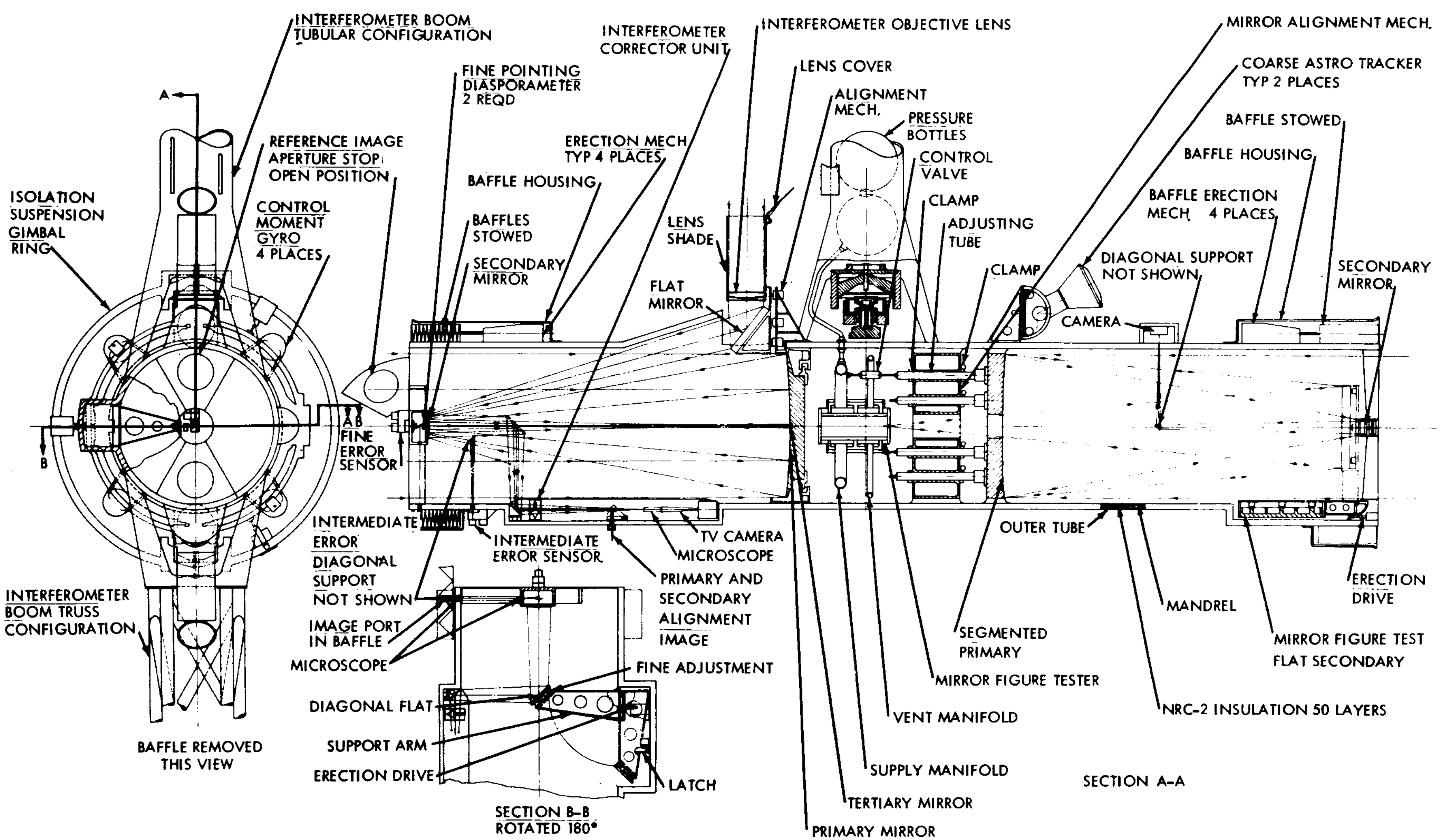


Figure 11. Six-tenths Meter Telescope

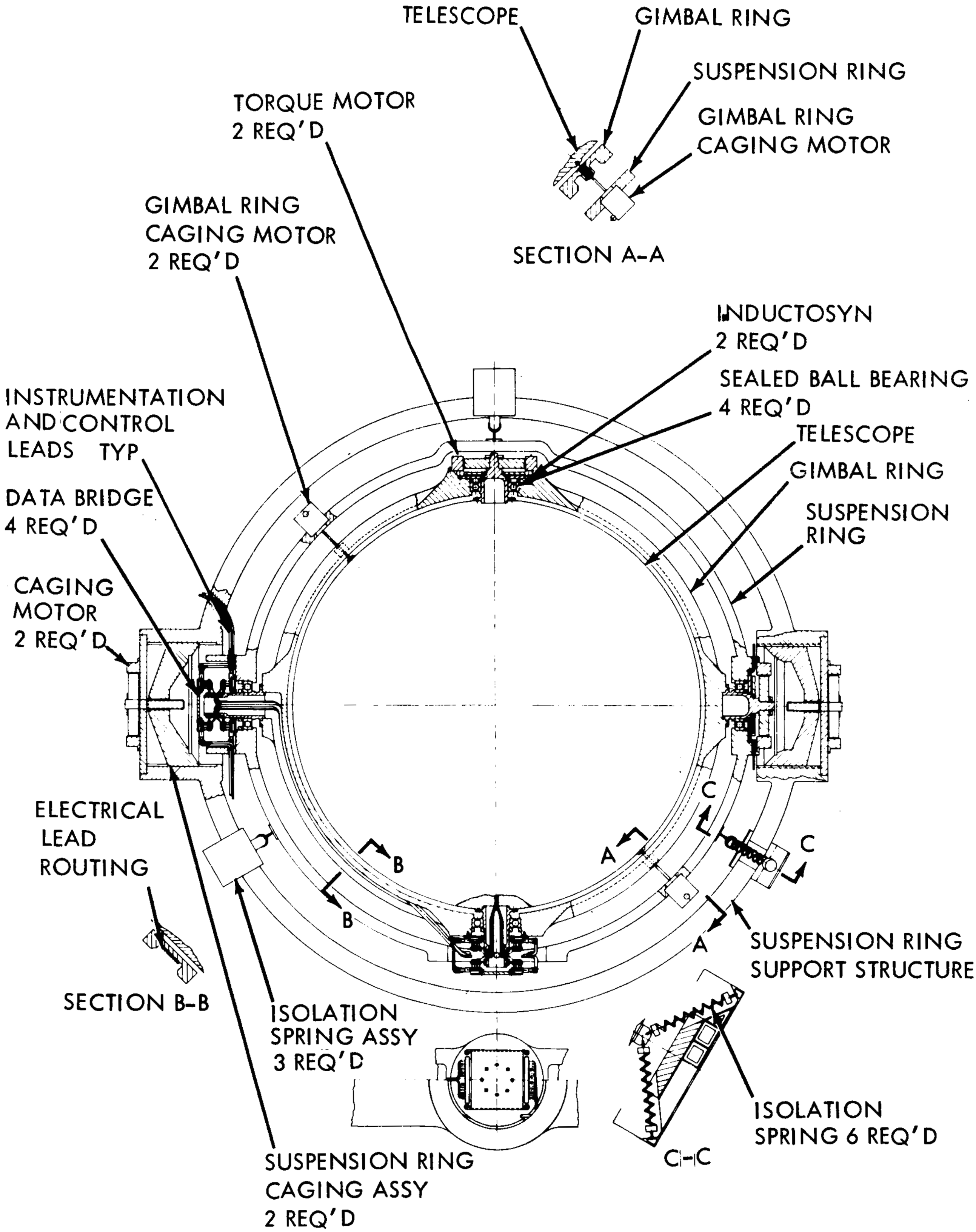


Figure 12. Isolation Technique - Spring Suspension

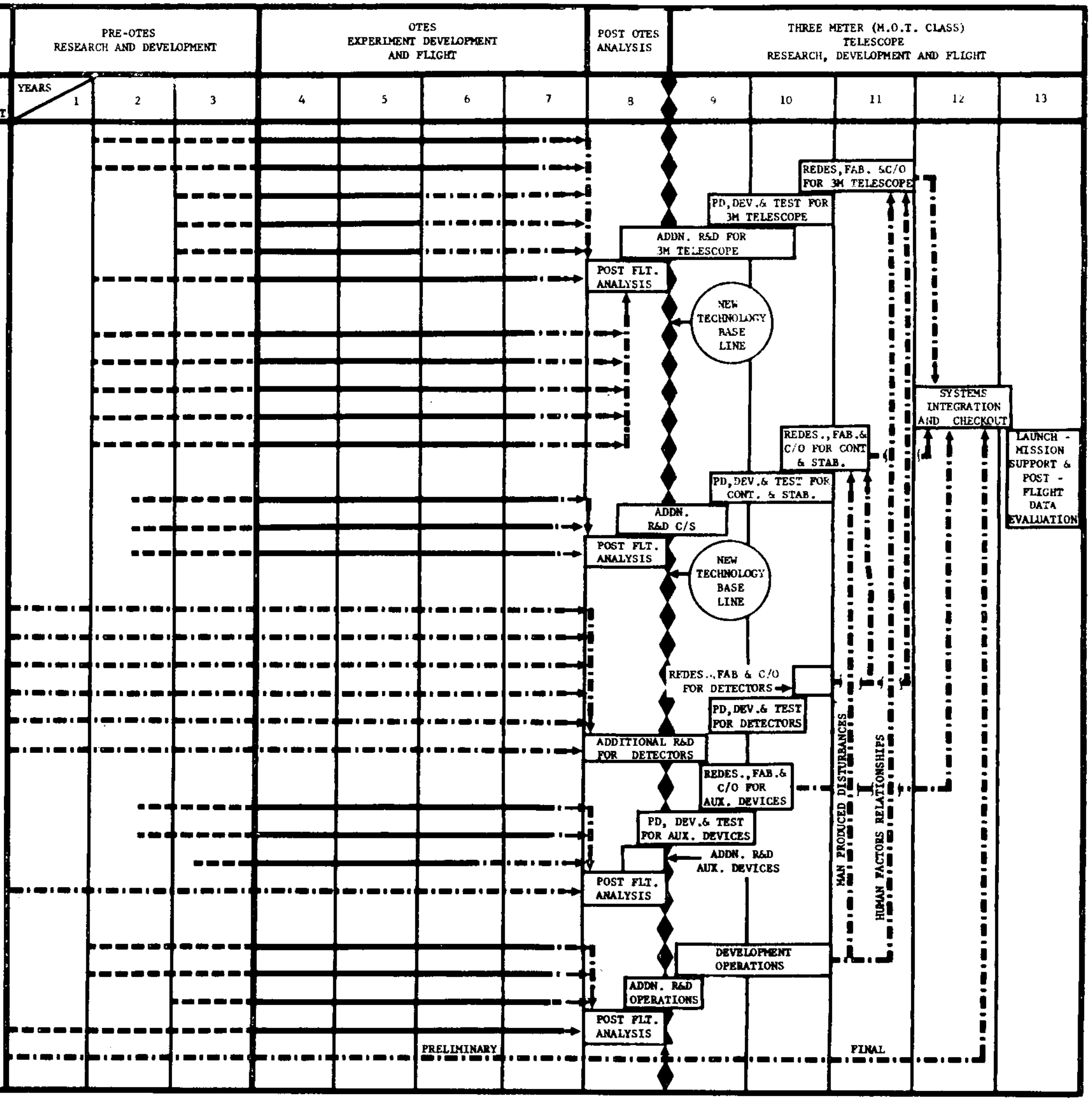
VI. DEVELOPMENT PLAN

One purpose of the OTAES study is to provide NASA with the comprehensive plan for the fulfillment of optical related space science technologies. As a guide, the OTAES technology development plan used two broad NASA goals: a large manned orbiting telescope and an interplanetary optical communications system. Most of the optical technology needs detailed in the first part of the OTAES study are satisfied by the achievement of these two goals.

A summary development plan was laid out for these two goals. Figures 13 and 14 are the plans for the manned orbiting telescope and interplanetary optical communication system, respectively. Specific OTAES experiments as well as prerequisite ground based testing to support these experiments appears in this schedule plan. Ground based testing not related to the OTAES experiments is identified by indicating specific technological areas in which such testing will be necessary. These tests, however, have not been time-phased.

It is evident by inspecting these plans that the OTAES flight experiments comprise a necessary step in the attainment of these planned goals. The technology advancements required to attain the long range goals are of such magnitude and complexity that a technology quantum jump approach does not appear feasible and that space experiments are a logical step to insure continuous technology advancement in all disciplines. Although the experiments can be designed to be flown singly and independently, much more will be gained by launching them in groups on a single vehicle or in closely timed launches.

TECHNOLOGY AREAS	RELATED EXPERIMENTS AND GROUND DEVELOPMENT: OTES EXPERIMENTS	OTES RELATED GROUND DEVELOPMENT	OTHER GROUND DEVELOPMENT
I. OPTICAL SUB-SYSTEM			
A. MATERIALS	10,11,15,16	G	REQUIRED
B. MIRROR FIGURE CONTROL	10,11,15	A,M	NOT REQD.
C. CONTAMINATION	16	G	REQUIRED
D. SURFACE DEGRADATION	16	G	NOT REQD.
E. MIRROR COATING	16	G	REQUIRED
F. THIN MIRROR	10,15,16	G	NOT REQD.
II. TELESCOPE STRUCTURE AND MECHANISMS			
A. PASSIVE THERMAL CONTROL	10,11,15	A,M,N	REQUIRED
B. SMALL DISPLACEMENT ACTUATORS	10,12,14,15	A,J,M,N	REQUIRED
C. ALIGNMENT SENSORS	10,11,15	A,J,M,N	REQUIRED
D. FOCUS SENSORS	10,11,15	A,J,M,N	REQUIRED
E. REMOTE ALIGNMENT PROCEDURES	10,11,15	A,J,M,N	REQUIRED
III. CONTROL/STABILIZATION			
A. TRACKING AND STABILIZATION	12,13		REQUIRED
B. ISOLATION AND GIMBALLING	12,13		REQUIRED
C. ACQUISITION	12	H	REQUIRED
IV. DETECTION AND CONDITIONING			
A. HIGH RESOLUTION DETECTORS		C,P	REQUIRED
B. DETECTORS SENSITIVE TO UV ONLY			REQUIRED
C. BROAD BAND PHOTO ELECTRIC DETECTORS		K	REQUIRED
D. HIGH DATA MAGNETIC TAPE STORAGE			REQUIRED
E. LOW LEVEL PHOTO ELECTRIC TUBE		C,K	REQUIRED
F. DRY DEVELOPMENT EMULSION		C	REQUIRED
V. AUXILIARY DEVICES			
A. VARIABLE DISPERSION SPECTROGRAPHS	12,13,16	F,J	REQUIRED
B. UV SPECTROGRAPH	12,13,16	F,J	REQUIRED
C. INTERFERENCE SPECTROMETERS	14		REQUIRED
D. BAFFLE SYSTEMS		E	REQUIRED
VI. OPERATIONS			
A. ERECTION AND CHANGE-OVER PROCEDURES	10,11,14,15	A	REQUIRED
B. LOGISTICS	10,11,14,15	C,E,G,N,	REQUIRED
C. OPERATING MODES	13	S	REQUIRED
D. LAUNCH ENVIRONMENT	ALL		REQUIRED
E. OBSERVATION PROGRAM AND PLAN	NONE	NONE	REQUIRED



NOTES: 1. SEE SECTION 16.0 FOR EXPERIMENT DEVELOPMENT DETAILS.

2. THIS FIGURE IDENTIFIES BUT DOES NOT SCHEDULE OTHER NEEDED GROUND DEVELOPMENT NOT SPECIFICALLY IN SUPPORT OF SPACE EXPERIMENTS.

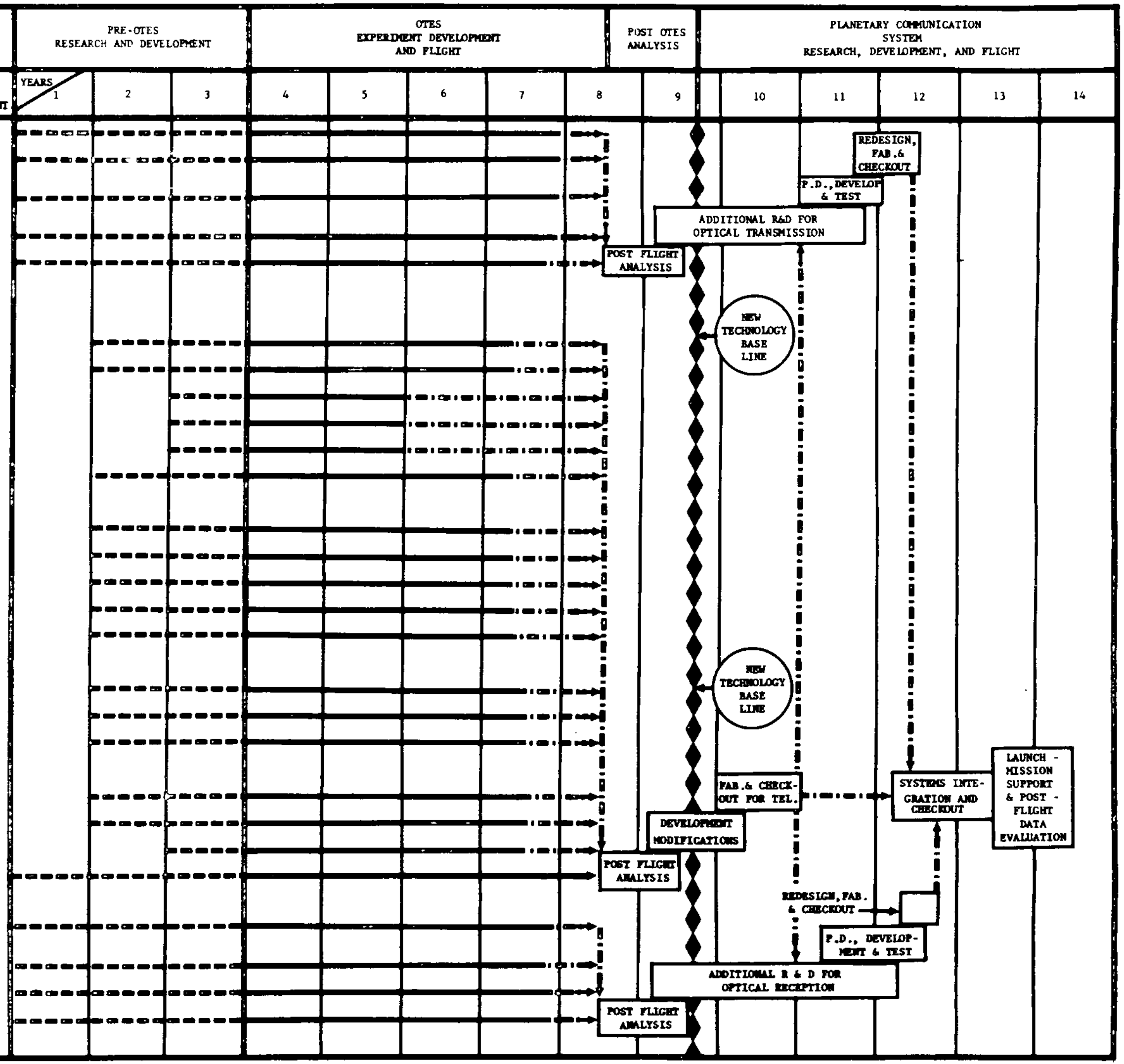
KEY

OTES EXPERIMENT DEVELOPMENT & FLIGHT
PRE-OTES RESEARCH & DEVELOPMENT
GROUND DEVELOPMENT & DELAY TIME

LONG RANGE ASTRONOMICAL TECHNOLOGY DEVELOPMENT MILESTONES

Figure 13

TECHNOLOGY AREAS	RELATED EXPERIMENTS AND GROUND DEVELOPMENT: OTES EXPERIMENTS	OTES RELATED GROUND DEVELOPMENT	OTHER GROUND DEVELOPMENT
I. OPTICAL TRANSMISSION			
A. PATH CHARACTERISTICS AND LINK DEGRADATION	1,2,3,4,5,8,9	B	REQUIRED
B. MEANS OF TRANSMISSION	1,2,3,4,5,6,7 8,9	B	REQUIRED
C. SPACE QUALIFIED SUPPORTING COMPONENTS	1,2,3,4,5,6,7 8,9		REQUIRED
D. OPTIMAL TRANSMITTING FREQUENCIES	1,2,3,4,8,9		REQUIRED
E. INFORMATION TRANSMISSION RATE	1,2,3,4		REQUIRED
II. SUPPORTING TELESCOPE TECHNOLOGY			
A. OPTICAL SUB-SYSTEMS			
1. MATERIALS	10,11,15,16	G	REQUIRED
2. MIRROR FIGURE CONTROL	10,11,15	A,M	NOT REQD.
3. CONTAMINATION	16	G	REQUIRED
4. SURFACE DEGRADATION	16	G	NOT REQD.
5. MIRROR COATING	16	G	REQUIRED
6. THIN MIRROR EVALUATION	10,15,16	G	NOT REQD.
B. TELESCOPE STRUCTURE & MECHANISMS			
1. PASSIVE THERMAL CONTROL	10,11,15	A,M,N	REQUIRED
2. SMALL DISPLACEMENT ACTUATORS	10,12,14,15	A,J,M,N	REQUIRED
3. ALIGNMENT SENSORS	10,11,15	A,J,M,N	REQUIRED
4. FOCUS SENSORS	10,11,15	A,J,M,N	REQUIRED
5. REMOTE ALIGNMENT PROCEDURES	10,11,15	A,J,M,N	REQUIRED
C. CONTROL AND STABILIZATION			
1. POINTING AND TRACKING	5,6,7	B,E,H	REQUIRED
2. POINT AHEAD	6		REQUIRED
3. ACQUISITION	5,7	B,H	REQUIRED
D. OPERATIONS			
1. ERECTION AND CHANGE-OVER PROCEDURES	10,11,14,15	A	REQUIRED
2. LOGISTICS	10,11,14,15	C,E,G,N	REQUIRED
3. OPERATING MODES	13	S	REQUIRED
4. LAUNCH ENVIRONMENT	ALL		REQUIRED
III. OPTICAL RECEPTION			
A. TYPE OF RECEIVER	1,2,3,4,5,6, 7,8,9	K,R	REQUIRED
B. MEANS OF DETECTION	1,2,3,4,6,9	K,R	REQUIRED
C. OPTIMAL RECEIVING FREQUENCY	1,2,3,4,8,9	K	REQUIRED
D. SIGNAL PROCESSING	1,2,3,4,6,7 8,9		REQUIRED



NOTES: 1. SEE SECTION 16.0 FOR EXPERIMENT DEVELOPMENT DETAILS.

2. THIS FIGURE IDENTIFIES BUT DOES NOT SCHEDULE OTHER NEEDED GROUND DEVELOPMENT NOT SPECIFICALLY IN SUPPORT OF SPACE EXPERIMENTS.

KEY

- OTES EXPERIMENT DEVELOPMENT AND FLIGHT
- PRE-OTES RESEARCH AND DEVELOPMENT
- GROUND EXPERIMENTS AND DELAY TIME

LONG RANGE OPTICAL PROPAGATION TECHNOLOGY DEVELOPMENT MILESTONES

Figure 14